"ANALYSIS OF MULTILEVEL NONCONTIGUOUS SPINAL FRACTURES- A RETROSPECTIVE STUDY "

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M.S. DEGREE-BRANCH II ORTHOPAEDIC SURGERY

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<u>CERTIFICATE</u>

This is to certify that the dissertation entitled ***" ANALYSIS OF MULTILEVEL NONCONTIGUOUS SPINAL FRACTURES-A RETROSPECTIVE STUDY "*** *is a bonafide record of work done by* ***Dr. R.PRABHA RAMKUMAR*** *in the Institute of Orthopaedics and Traumatology, Government Rajiv Gandhi Government General Hospital, Chennai, under the direct guidance of me.*

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DECLARATION

I, **Dr. R.PRABHA RAMKUMAR** , solemnly declare that the dissertation entitled **" ANALYSIS OF MULTILEVEL NONCONTIGUOUS SPINAL FRACTURES-A RETROSPECTIVE STUDY"** has been prepared by me under the able guidance and supervision of my guide **Prof.N.Deen Muhammad Ismail, M.S.ORTHO., D. ORTHO., Professor & Director I/C**, Institute of Orthopaedics and Traumatology, Madras Medical College, Chennai, in partial fulfilment of the regulation for the award of **M.S. (ORTHOPAEDICS)** degree examination of The Tamilnadu Dr. M.G.R. Medical University, Chennai to be held in April 2016.

This work has not formed the basis for the award of any other degree or diploma to me previously from any other university.

Signature of the candidate

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CONTENTS

INTRODUCTION

Spinal fractures usually results from high energy trauma. Fall from height, road traffic accidents and crush injuries are the most common mode of injuries in spinal fractures [1]. Incidence of spinal fractures is about 10,000 per year. It is increasing due to high incidence of motor vehicle accidents. Neurological deficit in cases of spinal fractures are common. Neurological injuries occurs in about 20% of all spinal injuries. Spinal fractures are very important cause of mortality and morbidity. Spinal fractures occur mostly in young and economically productive age group. This poses an economical burden not only in the family but also for the nation.

Recent advancements such as newer diagnostic imaging techniques, wide range of fixation options, intra operative monitoring devices are developed . But still spinal fractures stands as a challenge to orthopaedic surgeons .Research in the field of spinal fracture is of great essence to understand this complex entity. Yearly, hundreds of spinal fractures presents to Institute of Orthopaedics and Traumatology , Madras Medical College, which makes it an ideal place to do spinal fracture study.

The most common segments involved in case of spinal fractures is the dorsal and lumbar segment. Different spinal fracture patterns are due to various forces acting on the vertebra at the time of injury. Patterns of spinal fractures vary from patient to patient depending on the mode of injury, position of the spine during injury, direction of force and age of the patient.

Multiple level spinal fractures are not uncommon. Noncontiguous spinal fractures are rare and special form of multilevel spinal fractures. Fall from height and high energy road traffic accidents are main causes of multi level spine fractures.[2]. The major drawback in cases of multilevel noncontiguous spinal fractures are delay in diagnosis in emergency setup where the second lesion may be easily overlooked . [3]

Noncontiguous spinal fracture incidence ranges from 1.6% to 23.8% in various literatures, done in various countries and various setups. Previously it was proposed that noncontiguous multilevel spine fractures should have atleast three normal segments in between the fractured levels. But Iencean suggested that atleast one normal segment in between the injured levels is enough to lable it as noncontiguous [4]. Noncontiguous multilevel spine fractured patients have wide variety of problems ranging from mild local pain to quadriplegia or even death may occur. Many literatures are available for spinal fractures, but only a few speaks about noncontiguous spinal fractures.

Hence the knowledge of the incidence, patterns, treatment and outcomes are essential in cases of noncontiguous spinal fractures.

Aim of the study

Aim of this study is to evaluate the incidence, levels involved, patterns of fractures, neurological deficit created, treatment options and outcome of noncontiguous multilevel spinal fractures.

To study the outcome of noncontiguous multilevel spinal fractures treated either conservatively or surgically. To evaluate the outcome of single level or multilevel spinal stabilization surgeries both functionally and radiologically in case of noncontiguous spinal fractures and compare the therapeutic effect of conservative or surgical methods of treatment.

REVIEW OF LITERATURE

Diagnosis and treatment of spinal fractures dates back to 2500 BC to 1900 BC. The treatment of spinal fractures was described as early as 1500 years before Christ in the writings of Smith papyrus [5]. Hippocrates described spinal injuries with or without neurological injury. Spinal fractures without paralysis were treated by distraction, manual reduction and rest in supine position. Special tables were designed and used for these treatments by Hippocrates. Multilevel noncontiguous fractures are studied in detail in the following studies.

Griffith et al (1966) found a 3.2 % of incidence of multilevel noncontiguous spinal fractures in a study of 155 patients. Calenoff et al (1978) identified 30 patients with multilevel fractures among 710 patients with spinal fractures. Reported an incidence of 4.2 % . He also noted an average 53 days delay in diagnosis of the second lesion [7].

Korres et al reported 18 cases (7.8%) of multilevel noncontiguous spinal fractures. Three cases had complete neurological deficit, seven were having incomplete neurological deficit, eight cases had normal neurology. [8]

Amitava Gupta and W.L El Masri, from the Midland centre for spinal injuries, Oswestry conducted a study and found that among 935 patients with spinal fractures there was 9.7% incidence of noncontiguous multilevel spine fractures. It concluded that they had worst prognosis and 70% is associated with complete deficit. [9]

In a study conducted by D.S .Tearse, J.S Keene,D.S Drummond of University of Wisconsin, among 78 patients with spinal fractures, 13 had multilevel non contiguous spinal injuries [10]. 5 patients had a combination of cervical and thoracolumbar segments, 8 had a combination of thoracic and lumbar segments. Among this 8 patients 4 had posterior stabilization procedures. It concluded that incidence was 16.7% and suggested higher incidence is probably due to higher diagnostic facilities available.

Korres et al 2003 in his study of multilevel noncontiguous spinal fractures (from 1970 to 2000), 81 patients were evaluated. Of these 81 patients, thirty six patients had neurological deficit. 66 patients with stable spinal fractures were treated conservatively, whereas 15 patients with unstable spinal fractures required surgical stabilization. There was no neurologic deterioration either in the patients who had surgical stabilization or in the patients who were treated conservatively. Thirteen patients with score A on the American Spinal Injury Association neurologic impairment scale did not improve and had a high mortality rate (61.5%) . Although multiple level noncontiguous fractures of the spine are uncommon, they constitute a threat to neurologic function, and therefore warrant radiographic evaluation of the entire spine with multiple injuries [11].

The study by Xiao Feng Lian et al (2007) reported the outcomes of 30 noncontiguous multilevel spinal fractures. Ten cases were treated conservatively (group A), eight cases were operated at only one level (group B) and 12 cases were treated surgically at both levels (group C). All cases were followed up for 14–60 months (mean 32 months). Initial mobilisation with a wheelchair or crutches in group A was 9.2±1.1 weeks, which was significantly longer than groups B and C with 6.8±0.7 weeks and 3.1±0.4 weeks, respectively. Operative time and blood loss in group C was significantly more than group B. The neurological deficit improved in six cases in group A (60%), six in group B (75%) and eight in group C (80%). Correction of kyphotic deformity was significantly superior in groups C and B at the operated level, and increasing deformity occurred in groups A and B at the non-operated level. All three treatment strategies were suitable for multilevel noncontiguous spinal fractures and individualised treatment should be used in these patients. In the patients treated surgically, the clinical and radiographic outcomes are much better than conservative treatment.[12]

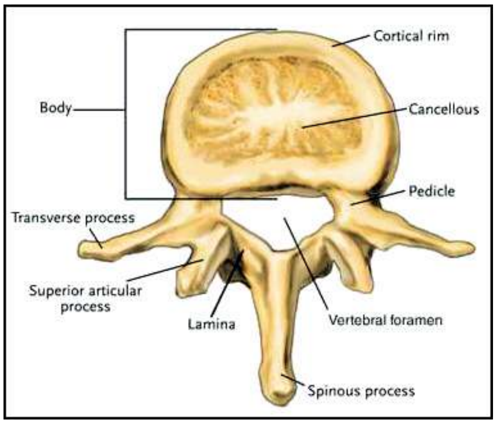
APPLIED ANATOMY

Spine forms the main basis for human skeleton. It is made up of bony vertebrae and the intervening intervertebral discs. The stability of the human spine is mainly by the supporting ligaments and the paraspinal muscles around.

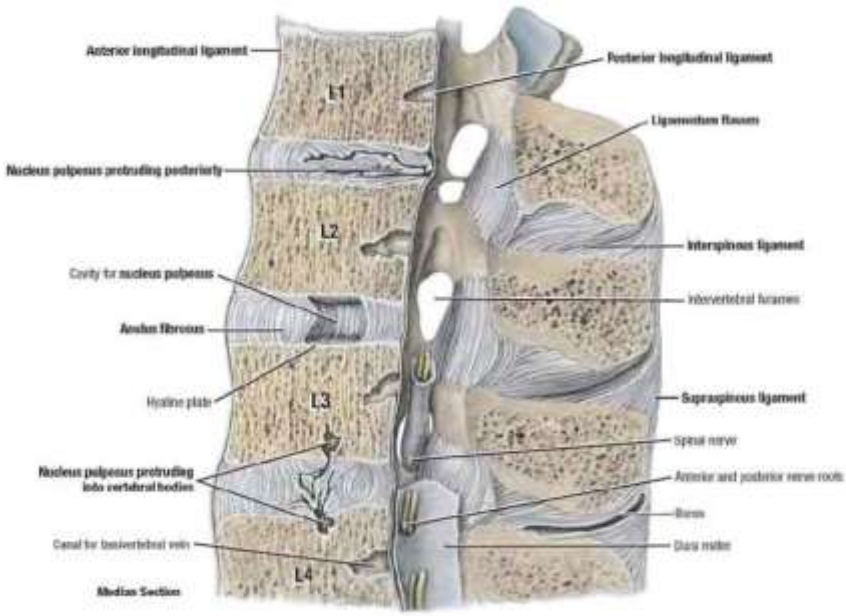
Spine consists of thirty three vertebra . It is divided into 5 segments depending on the biomechanics and anatomy.

Name of the segment	**No of vertebrae**
Cervical	7
Dorsal	12
Lumbar	5
Sacrum	5
Coccyx	4

Out of these 33 vertebra, 24 belong to mobile segment group and 9 belong to immobile segment group [13]. Vertebra has two important parts - the body and a neural arch. Neural arch contains two pedicles and two laminae which joins to form the spinous process. It consists of two transverse process laterally and superior & inferior articular facet joints which helps in the movements of the spine. The bony vertebra safeguards the delicate neural elements.

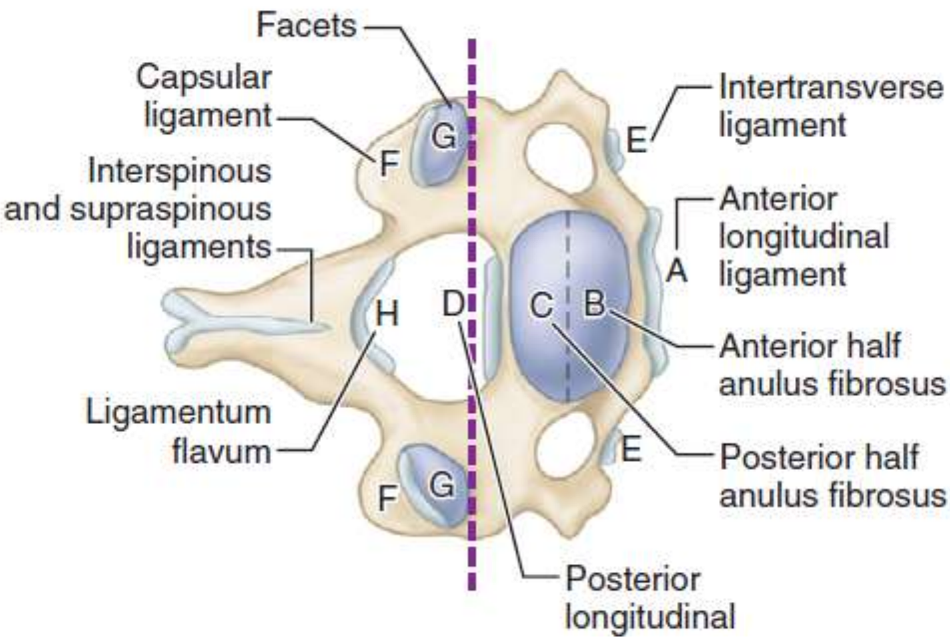


In between two vertebral bodies, there is an intervertebral disc. It is made up of two layers – outer annulus fibrosus , inner nucleus pulposus [14]. Each vertebra is connected to its adjacent vertebra by means of facet joints. It is a synovial joint covered by articular cartilage and lined by synovial membrane. The whole vertebra is bridged by ligaments – anterior longitudinal ligament, posterior longitudinal ligament, ligamentum flavum, supra & inter spinous ligaments.



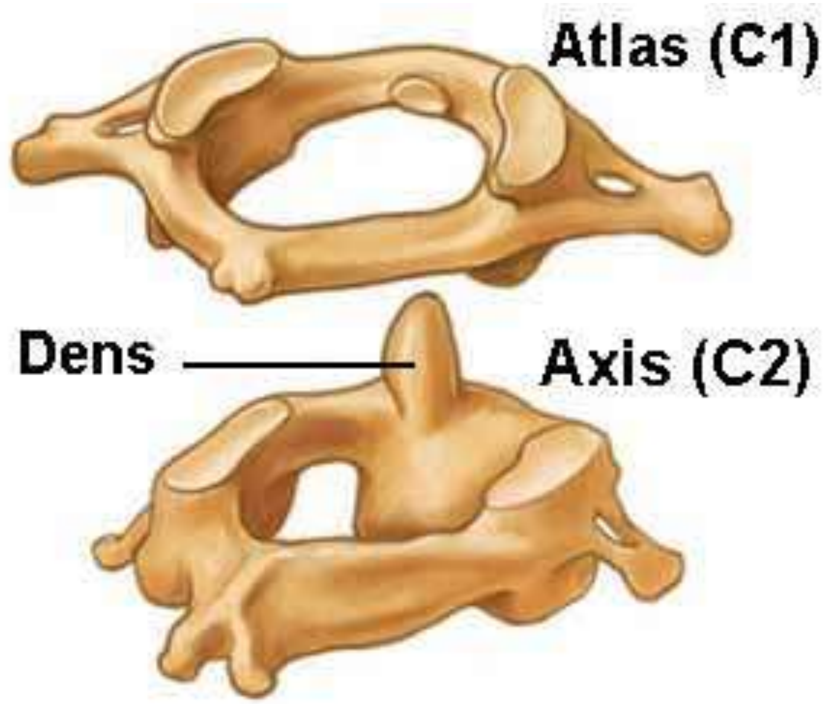
CERVICAL SPINE:

Cervical spine consists of atlas (C1), axis with dens (C2) and C3-C7. Cervical spine bears less weight than the rest so it is relatively small and thin. Lateral edge of superior surface of each body is sharply turned upward to form the uncinate process. Transverse foramina present on either side that transmits the vertebral arteries. Cervical pedicle connects posterior vertebral arch to the vertebral body. Lateral mass is the site of screw fixation in posterior stabilization of cervical spine [16].



Atlanto-Axial complex :

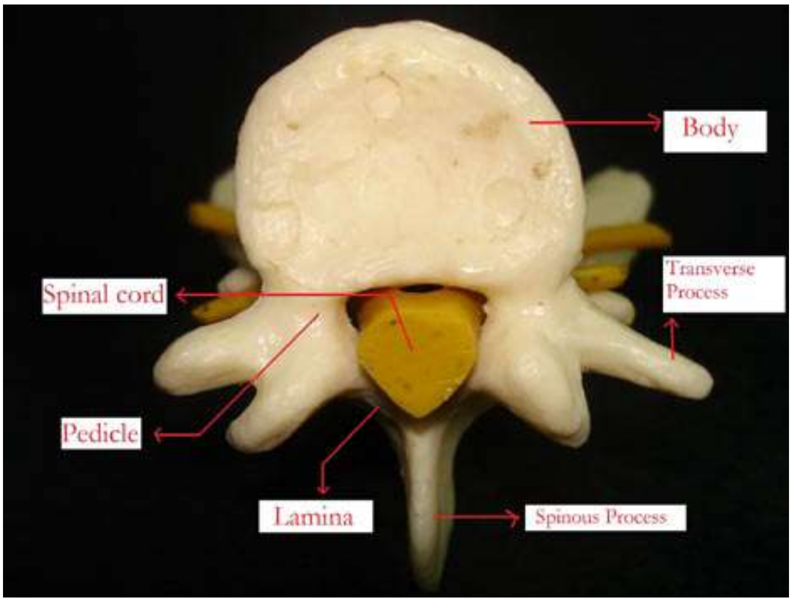
Atlanto -axial joint permits nutational and rotational movement of the head. C1 consists of a bony ring with anterior & posterior arch connected by two lateral mass. C1 does not have a body.Axis (C2) provides a bearing surface on which atlas may rotate.It has a unique vertically projecting odontoid process that serves as a pivotal restraint against horizontal displacement of C1.



ANATOMY OF DORSO-LUMBAR SPINE:

Pedicle anatomy :

Pedicle is the strongest part of the vertebrae with strong shell of cortical bone and a core of cancellous bone bridging the body under posterior spinal elements. Width is narrower than height of the pedicle. In dorsal vertebra, pedicle is widest at D11 level , whereas L5 is the largest pedicle in lumbar region.[15]



Cauda equina is very close to the pedicle on the medial side below L1. The vertical diameter (height) of the pedicle increases from 7mm to 15mm from D3 to L5 and the horizontal diameter (width) of the pedicle increases from 7mm to 16mm from D3 to L5. The direction of the pedicle is almost sagittal from D4 to L4. The angulation is about 10 degrees at thoracolumbar junction and at L5 it is about 30 degrees.

Vascular supply of Spinal Column

The thoracolumbar spine receives its blood supply from posterior intercostal and lumbar arteries as inter segmental arteries. The veins form a plexus along the entire vertebral column. The external vertebral veins are anterior and posterior. They receive tributaries from vertebral bodies and anastomose with the internal plexus of veins. The internal plexus are four in number, two anterior and two posterior which drains the vertebral bodies and spinal cord. The basivertebral veins drain the posterior foramina of the vertebral bodies.

The intervertebral veins mainly drains the spinal cord and ends in the vertebral venous plexus.

Lymphatic Drainage

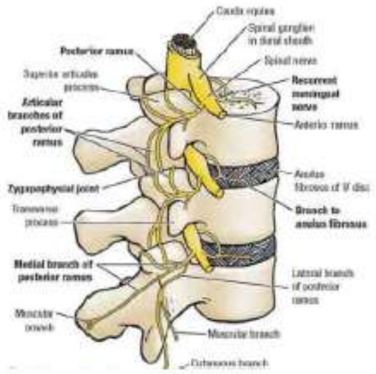
The lymphatics from thoracic region drain into intercostal nodes and the lumbar column drains into para aortic and retro aortic nodes.

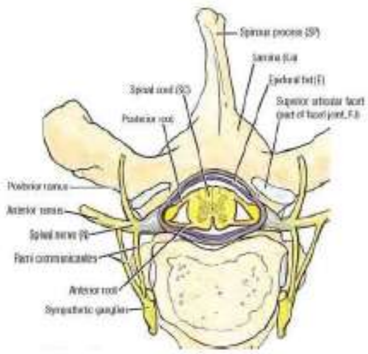
Innervation

The vertebral column is innervated by spinal nerves . The sympathetic system supplies via the grey rami communicantes. The spinal nerve supplies the facet joints and the periosteum of the posterior bony elements.

NEUROANATOMY

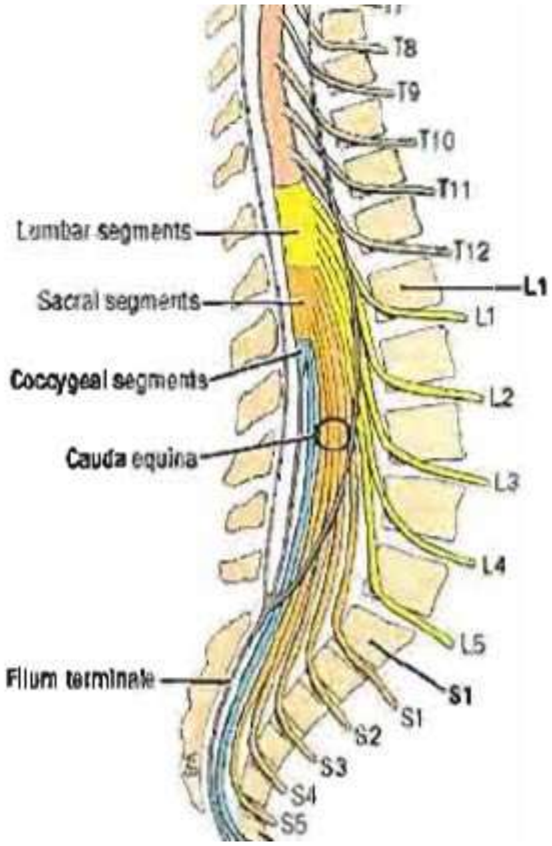
The spinal cord extends from the foramen magnum to lower border of L1. It is oval in shape. It is enclosed by Duramater, Arachnoid mater and Piamater. Between archnoid and piamater is the subarachnoid space which contains cerebrospinal fluid. It terminates in conus medullaris from where filum terminale descends downwards. Roots arising from the anterolateral sulcus forms the ventral root and those arising from the posterolateral sulcus forms the dorsal root which terminates in a ganglion before joining with the ventral root to form a spinal nerve. There are 31 pairs of spinal nerves including 8 Cervical, 12 Thoracic, 5 Lumbar, 5 Sacral and 1 Coccygeal. The Spinal nerves below L1 exit through their corresponding neural foramina as Cauda equina.





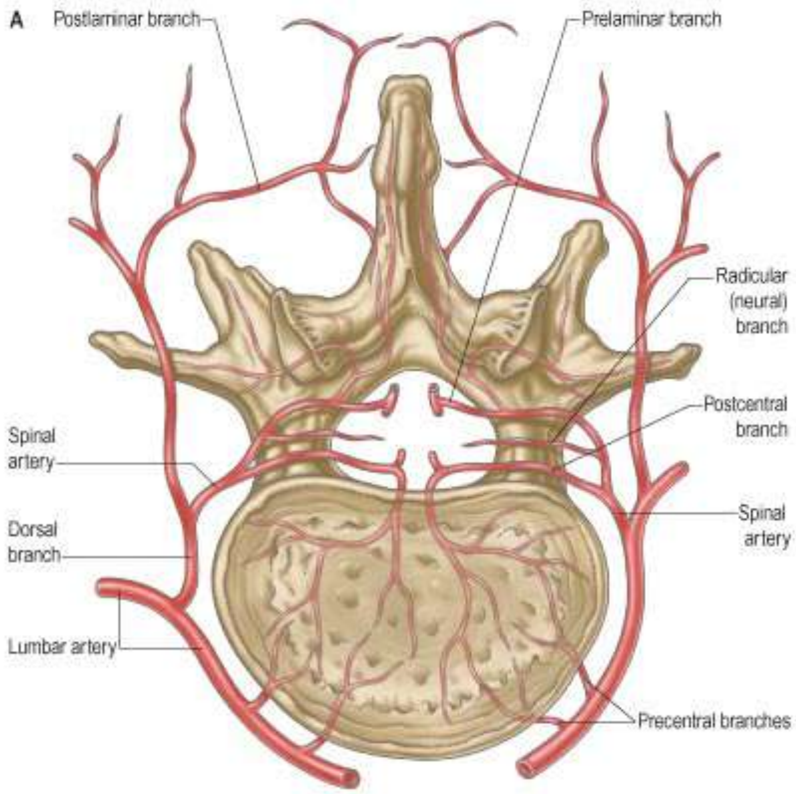
VERTEBRAL LEVELS OF SPINAL CORD SEGMENTS

Bony vertebral Level	Spinal Segment level
1 Cervical	One level is added
2. Thoracic D1 –D6	Two levels are added
3. Thoracic D7 – D9	Three levels are added
4. Thoracic D10	L1 –L2
5. Thoracic D11	L3 –L4
6. Thoracic D12	L5
7. Lumbar L1	Sacral segments

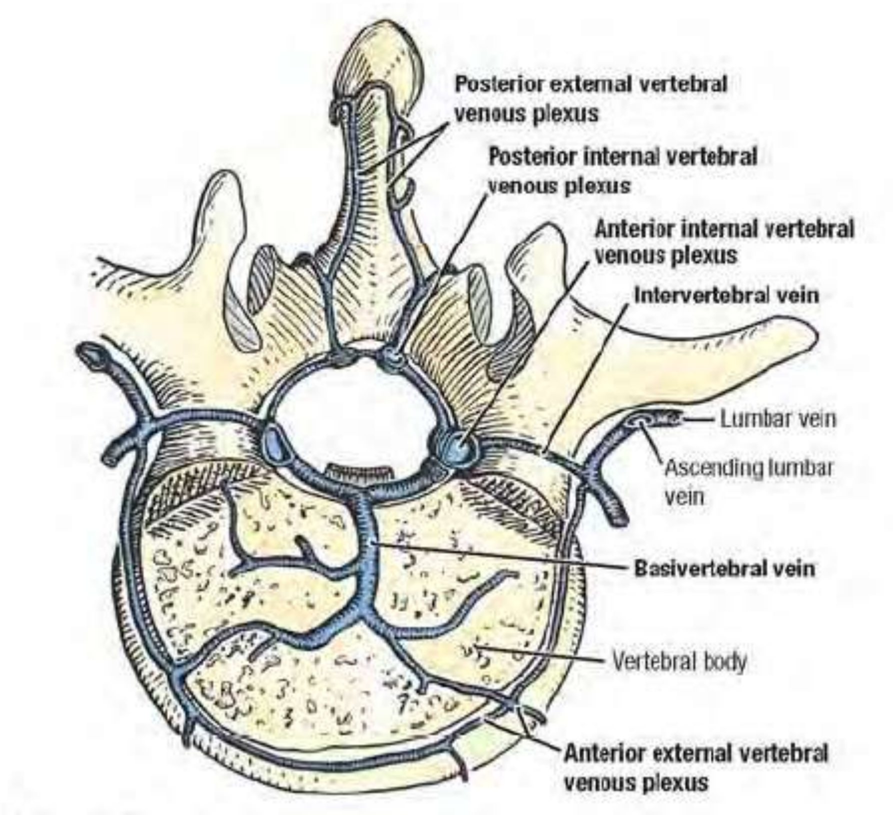


VASCULAR SUPPLY OF SPINAL CORD

The spinal cord is supplied by both longitudinal and segmental vessels. The longitudinal vessel include one anterior spinal and two posterior spinal arteries. The anterior spinal artery arises from the vertebral artery. The posterior spinal artery arises either from the ipsilateral vertebral artery or from the posterior inferior cerebellar artery. The segmental arteries arise from the deep cervical, intercostal and lumbar arteries. They form the pial plexus which supplies the cord. Segmental medullary feeder arteries also supply the cord. There are 2 to 17 anterior medullary feeder arteries and 6 to 25 posterior medullary feeder arteries. The largest anterior medullary feeder artery is the Artery of Adamkiewicz [17]. It is located on the left side at the level of T9 – T11 arising from the lower posterior intercostals arteries. The anterior spinal artery supplies the anterior two thirds of the cord. The posterior one third of the cord is supplied by the branch from the posterior spinal artery and the pial plexus. The intraspinal and extraspinal structure are supplied by a pair of segmental arteries at each vertebral level. In the cervical segments it arises from the vertebral arteries, costocervical and thyrocervical trunk. In the thoracic and lumbar segments it arises from the aorta. The sacral segments are supplied by lateral sacral, iliolumbar and middle sacral arteries. The segmental arteries divide into various branches at the intervertebral foramen forming the distribution points. The blood supply to the thoracic cord between T4 – T9 is poor.



Venous drainage of the spinal cord is highly variable. There are two sets of veins - veins of the spinal cord and veins that fall within the Batson plexus. The veins of the spinal cord drain into the plexus of Batson. The Batson plexus is a large and complex venous channel extending from the base of the skull to the coccyx. It communicates directly with the superior and inferior vena cava system and the azygos system. There are three components of the Batson plexus of veins which includes the extradural vertebral venous plexus, the extravertebral venous plexus and the veins of the bony structures of the spinal column. They communicate directly with the venous system draining the head, chest and abdomen which allows the metastatic spread of neoplastic material or infectious disease from the pelvis to the vertebral column [18].



CLINICAL ANATOMY

The vertebral column divided into five regions - Cervical , Dorsal , Lumbar, Sacrum and Coccyx.

REGION	**VERTEBRA**
CERVICAL	C1 TO C7
DORSAL	D1 TO D12`
LUMBAR	L1 TO L5
SACRUM	S1 TO S5
COCCYX	Cx1 TO Cx4

BIOMECHANICS OF THORACOLUMBAR SPINE

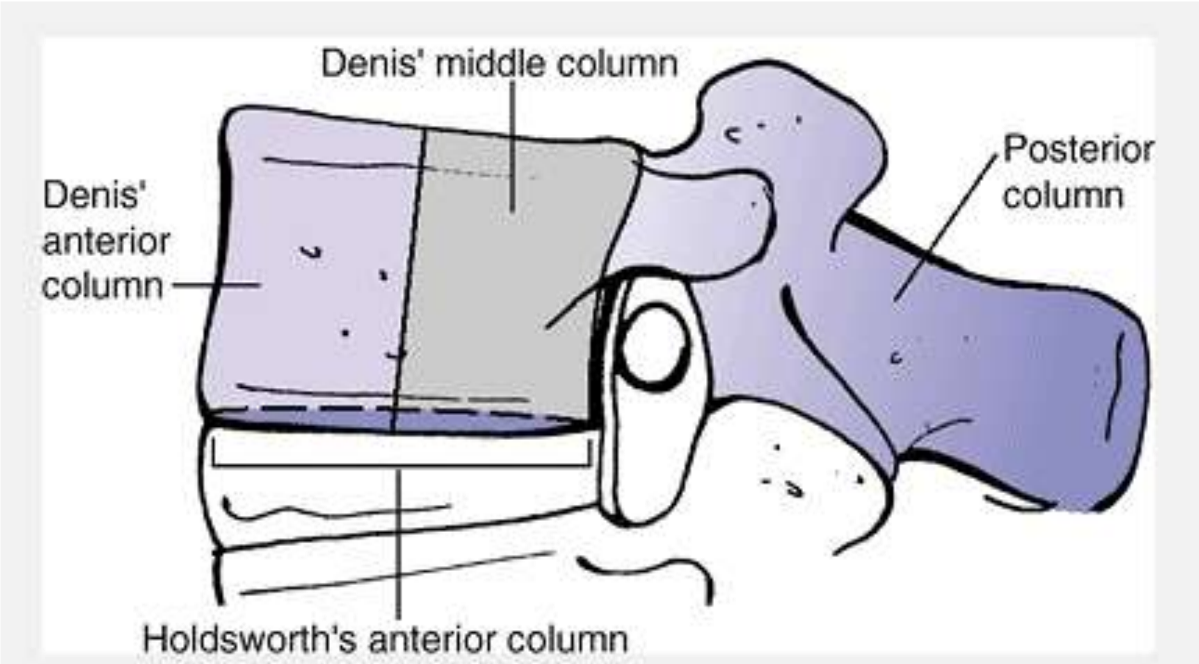
The dorsolumbar junction represents a transition zone between the rigid thoracic spine and the flexible lumbar spine [19]. The thoracic musculature, rib cage and facet joints contribute to a stiff thoracic spine which allows only rotation . There is also a change in sagittal alignment between the kyphotic thoracic segment and lordotic lumbar segment. There is approximately 4 degrees of flexion-extension at each intervertebral segment from T1 to T6 and a high degree range of flexion about 12 degrees at the thoracolumbar junction. The lateral flexion allowed in thoracic segment is about 8 degrees whereas in the lumbar spine it is about 2 degrees [20]. This is due to the sagittal orientation of facet joints in the lumbar spine .

Pathomechanics of injury

Disruption of the costovertebral joints results in substantial increases in intervertebral motion within the thoracic spine [21]. The forces acting in spinal trauma include axial loading, flexion, extension, shear and axial rotation. The damage occurs as a result of combination of these forces. Pure axial loads or compressive forces result in end plate fractures , anterior wedge compression fractures, and burst fractures. Flexion forces with center of rotation occurring near the posterior longitudinal ligament results in a compressive load applied to the anterior vertebral body and a corresponding distraction force within the posterior elements. When a sagittal rotation centers to a point in front of the spine, primary distraction forces act on both the anterior and posterior elements. Extension type injuries produce tensile forces in the anterior spine with compressive forces applied to the posterior elements. Pure axial load with minimal extension is the primary mechanism leading to burst fractures with widening of pedicles and retropulsion of fragments [22].

Denis Three column Theory

Denis developed a three column theory for dorsolumbar injuries [23]. He divided the spinal column into three parts . The anterior column consists of anterior longitudinal ligament, anterior half of the vertebral bodies and anterior half of the annulus with its nucleus pulposus. The middle column consists of posterior half of the vertebral bodies, posterior half of the annulus with its nucleus pulposus and posterior longitudinal ligament. The posterior column consists of neural arch , ligamentum flavum, facet joints, interspinous and supraspinous ligaments. The movements occurring at dorsolumbar spine are rotation at dorsal region and flexion, extension and lateral bending at lumbar region. The movements diminish with the age of the patient. The local vertebral alignment at the level of injury and the magnitude of impact force determine the pattern of injury. Two adjacent vertebrae and the intervening soft tissue between them form a motion segment. If a motion segment has one anterior and one posterior element or all the posterior and one anterior element intact, then it will remain stable under normal physiological loads.



CLASSIFICATION-CERVICAL SUB AXIAL INJURIES:

Allen Ferguson classification:

	COMPRESSIVE FLEXION—FIVE STAGES
Compressive flexion stage 1	Blunting of the anterosuperior vertebral margin to a rounded contour, with no evidence of failure of the posterior ligamentous complex.
Compressive flexion stage 2	In addition to the changes seen in stage 1, obliquity of the anterior vertebral body with loss of some anterior height of the centrum. The anteroinferior vertebral body has a "beak" appearance, concavity of the inferior endplate may be increased, and the vertebral body may have a vertical fracture.
Compressive flexion stage 3	In addition to the characteristics of a stage 2 injury, fracture line passing obliquely from the anterior surface of the vertebra through the centrum and extending through the inferior subchondral plate and a fracture of the beak.
Compressive flexion stage 4	Deformation of the centrum and fracture of the beak with mild (<3 mm) displacement of the inferoposterior vertebral margin into the spinal canal.
Compressive flexion stage 5	Bony injuries as in stage 3 but with more than 3 mm of displacement of the posterior portion of the vertebral body posteriorly into the spinal canal. The vertebral arch remains intact, the articular facets are separated, and the interspinous process space is increased at the level of injury, suggesting a posterior ligamentous disruption in a tension mode.
	VERTICAL COMPRESSION—THREE STAGES
Vertical compression stage 1	Fracture of the superior or inferior endplate with a "cupping" deformity. Failure of the endplate is central rather than anterior, and posterior ligamentous failure is not evident.
Vertical compression stage 2	Fracture of both vertebral endplates with cupping deformities. Fracture lines through the centrum may be present, but displacement is minimal.
Vertical compression stage 3	Progression of the vertebral body damage described in stage 2. The centrum is fragmented, and the displacement is peripheral in multiple directions. Most commonly, the centrum fails, with significant impaction and fragmentation. The posterior aspect of the vertebral body is fractured and may be displaced into the spinal canal. The vertebral arch may be intact with no evidence of ligamentous failure, or it may be comminuted with significant failure of the posterior ligamentous complex; the ligamentous disruption is between the fractured vertebra and the one below it.
	DISTRACTIVE FLEXION—FOUR STAGES
Distractive flexion stage 1	Failure of the posterior ligamentous complex, as evidenced by facet subluxation in flexion, with abnormal divergence of the spinous process.
Distractive flexion stage 2	Unilateral facet dislocation (the degree of posterior ligamentous failure ranges from partial failure sufficient only to permit the abnormal displacement to complete failure of the anterior and posterior ligamentous complexes, which is uncommon). Subluxation of the facet on the side opposite the dislocation suggests severe ligamentous injury. In addition, a small fleck of bone may be displaced from the posterior surface of the articular process, which is displaced anteriorly. Widening of the uncovertebral joint on the side of the dislocation and displacement of the tip of the spinous process toward the side of the dislocation may be seen. Beatson serially divided the posterior interspinous ligaments, facet capsule, posterior longitudinal ligament, anulus fibrosus, and anterior longitudinal ligament and found that unilateral facet dislocation can occur with rupture of only the posterior interspinous ligament and the facet capsule.
Distractive flexion stage 3	Bilateral facet dislocations, with approximately 50% anterior subluxation of the vertebral body. Blunting of the anterosuperior margin of the inferior vertebra to a rounded corner may or may not be present. Beatson showed that rupture of the interspinous ligament, the capsules of both facet joints, the posterior longitudinal ligament, and the anulus fibrosus of the intervertebral disc was necessary to create this lesion.
Distractive flexion stage 4	Full vertebral body width displacement anteriorly or a grossly unstable motion segment, giving the appearance of a "floating" vertebra.
	COMPRESSIVE EXTENSION—FIVE STAGES
Compressive extension stage 1	Unilateral vertebral arch fracture with or without anterior rotatory vertebral displacement. Posterior element failure may consist of a linear fracture through the articular process, impaction of the articular process, and ipsilateral pedicle and lamina fractures, resulting in the "transverse facet" appearance on anteroposterior radiographs, or a combination of ipsilateral pedicle and articular process fractures.
Compressive extension stage 2	Bilaminar fractures without evidence of other tissue failure. Typically, the laminar fractures occur at multiple contiguous levels.

Compressive extension stage 3	Bilateral vertebral arch fractures with fracture of the articular processes, pedicles, lamina, or some bilateral combination, without vertebral body displacement.
Compressive extension stage 4	Bilateral vertebral arch fractures with partial vertebral body width displacement anteriorly.
Compressive extension stage 5	Bilateral vertebral arch fracture with full vertebral body width displacement anteriorly. The posterior portion of the vertebral arch of the fractured vertebra does not displace, and the anterior portion of the arch remains with the centrum. Ligament failure occurs at two levels: posteriorly between the fractured vertebra and the one above it and anteriorly between the fractured vertebra and the one below it. Characteristically, the anterosuperior portion of the vertebra below is sheared off by the anteriorly displaced centrum.
	DISTRACTIVE EXTENSION—TWO STAGES
Distractive extension stage 1	Either failure of the anterior ligamentous complex or a transverse fracture of the centrum. The injury usually is ligamentous, and there may be a fracture of the adjacent anterior vertebral margin. The radiographic clue to this injury is abnormal widening of the disc space.
Distractive extension stage 2	Evidence of failure of the posterior ligamentous complex, with displacement of the upper vertebral body posteriorly into the spinal canal, in addition to the changes seen in stage 1 injuries. Because displacement of this type tends to reduce spontaneously when the head is placed in a neutral position, radiographic evidence of the displacement may be minimal, rarely greater than 3 mm on initial films with the patient supine.
	LATERAL FLEXION—TWO STAGES
Lateral flexion stage 1	Asymmetrical compression fracture of the centrum and ipsilateral vertebral arch fracture, without displacement of the arch on the anteroposterior view. Compression of the articular process or comminution of the corner of the vertebral arch may be present.
Lateral flexion stage 2	Lateral asymmetrical compression of the centrum and either ipsilateral displaced vertebral arch fracture or ligamentous failure on the contralateral side with separation of the articular processes. Ipsilateral and compressive and contralateral disruptive vertebral arch injuries may be present.

CLASSIFICATION OF THORACOLUMBAR FRACTURES

McAffe et al Classification [24]:

1. Wedge compression fracture

2. Stable burst fracture

3. Unstable burst fracture

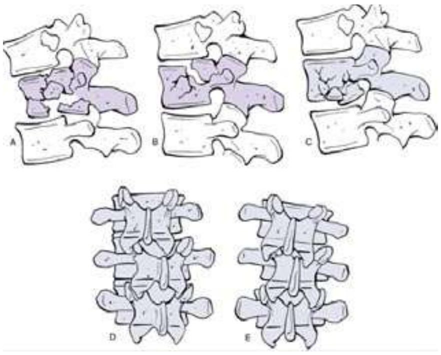
4. Chance fracture

5. Flexion distraction injuries

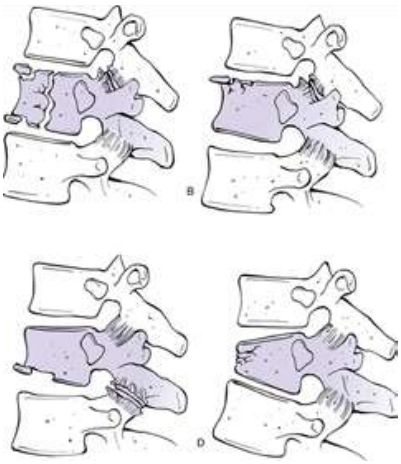
6. Translational injuries

DENIS CLASSIFICATION:

1).Burst fractures



2) Wedge compression fracture:

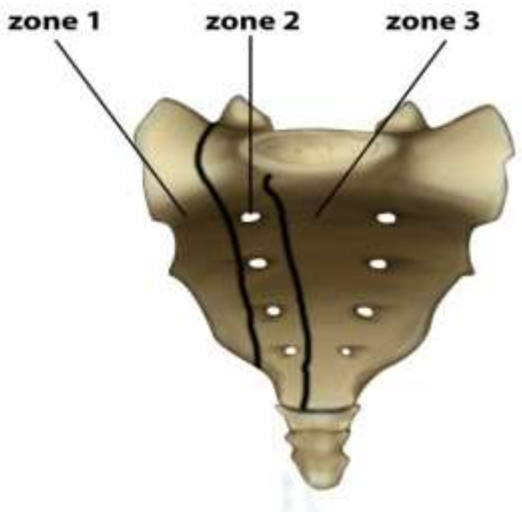


3) Fracture Dislocation:

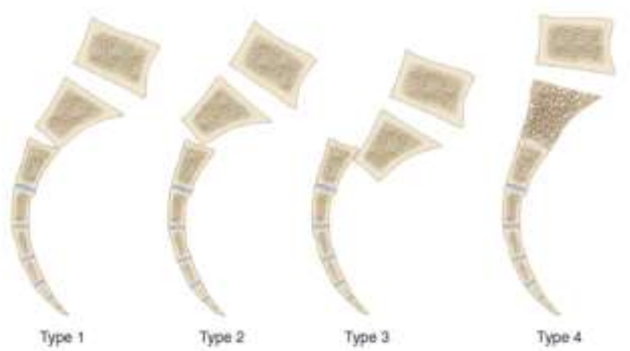
4) Flexion Distraction Injuries

CLASSIFICATION OF SACRAL FRACTURES :

DENIS CLASSIFICATION :



Roy-camille subclassification of denis zone-3 fractures:



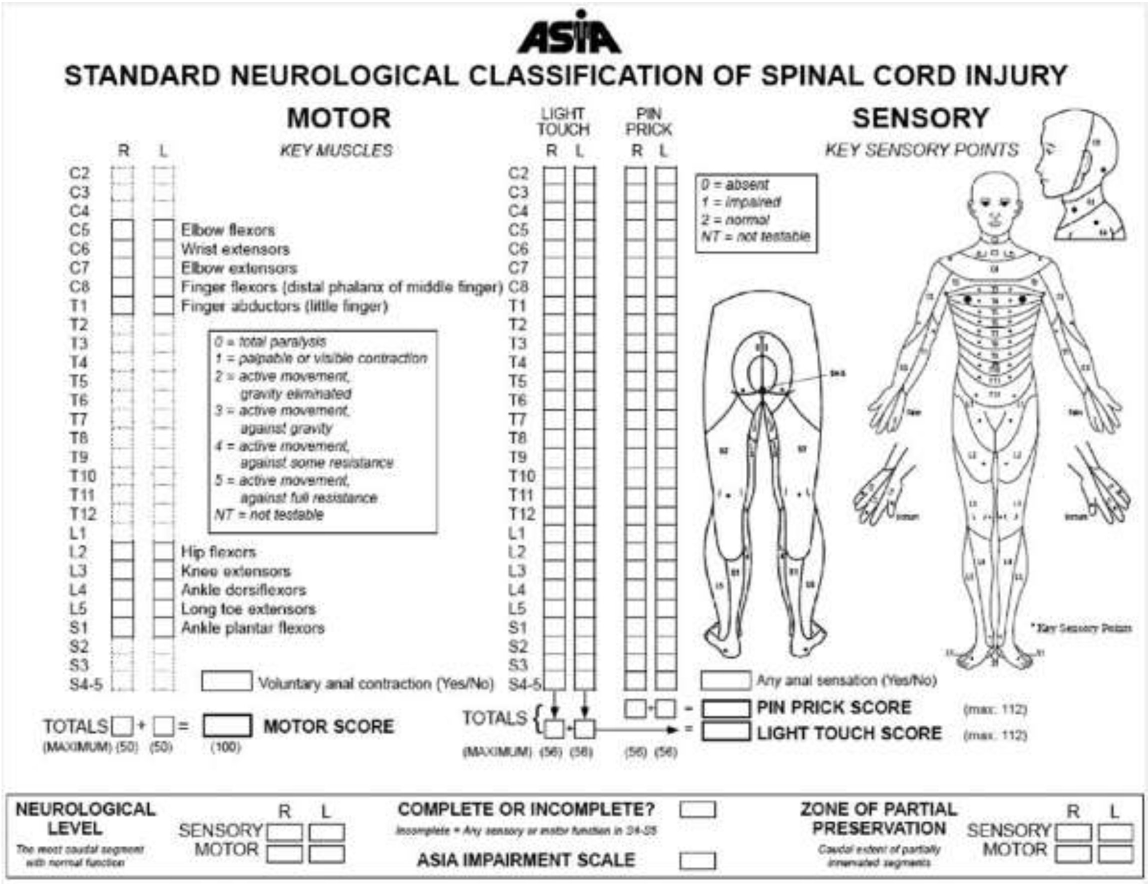
Roy-Camille and Strange-Vognsen and Lebech subclassifications of Denis zone 3 fractures [25] are Type 1- angulation with no translation; Type 2- angulation and translation; Type 3-complete displacement of cephalad and caudal sacrum; Type 4- segmental comminution.

CLINICAL EVALUATION

Any patient suspected of spinal trauma should be evaluated in emergency trauma ward for Airway, Breathing and Circulation. Initial resuscitation is done with nasal oxygen and intravenous fluids. Cervical spine immobilization is done with hard cervical collar. Neurological status and level of consciousness should be evaluated with aid of Glasgow coma scale to rule out any head injury [26].Chest and abdominal examination should be done to rule out pulmonary or visceral injuries. Bladder should be catheterized to rule out bladder/urethral injury and to monitor urine output.

Spine examination is done after stabilizing the patient with minimal shifting of the patient . Log rolling procedure is done to roll the patient to his/her side for the spine examination [27].

Spine examination should include whole of the spine looking for tenderness to check for multilevel spine fractures. Neurological assessment is done with ASIA scale. This includes testing the motor power of ten muscles on each side of the body innervated by C5 to T1 and L2 to S1 and pin prick assessment at 28 specific sensory dermatomes on each side of the body. The sum of motor and sensory score is calculated and compared with normal. Bulbocavernous reflex should be examined to check for spinal shock. Then rectal examination should be carried out to test the resting tone, voluntary contraction and perianal sensation [28].



Following ten key muscle groups and their corresponding nerve root levels are tested in a patient with spinal cord injury.

LEVEL	MUSCLE GROUP
C5	Elbow flexors- Brachialis and Biceps
C6	Wrist extensors- Extensor Carpi radialis longus and brevis

C7	Elbow Extensors – Triceps
C8	Finger flexors-Flexor digitorum profundus to middle finger
T1	Small finger abductors-Abductor digiti minimi
L2	Hip flexors- Iliopsoas
L3	Knee extensors- Quadriceps
L4	Ankle dorsiflexors
L5	Long toe extensors- Extensor hallucis longus
S1	Ankle plantar flexors- Gastronemius and Soleus

Complete spinal cord injury

No sensation or voluntary motor function is present caudal to the level of injury in the presence of an intact bulbocavernosus reflex. Reflex returns below the level of the cord injury [29].

Incomplete spinal cord injury

Some neurologic function persists caudal to the level of injury after the return of the bulbocavernosus reflex. Sacral sparing is represented by perianal sensation, voluntary rectal motor function and great toe flexor activity. It indicates partial continuity of white mater long tracts with incomplete cord injury, with greater chance of recovery of cord function following resolution of spinal shock. The greater the function distal to the lesion and faster the recovery, better the prognosis.

The spinal cord injured patients are graded into five types by ASIA score and by Frankel et al Grading [30].

AMERICAN SPINAL INJURY ASSOCIATION SCORE

A	Complete	No motor or sensory function in the lowest sacral segment
B	Incomplete	Sensory function below neurological level & in S4 S5, no motor function below neurological level
C	Incomplete	Motor function is preserved below the neurological level, key muscle groups below neurological level have a grade <3
D	Incomplete	Motor function is preserved below the neurological level, key muscle groups below neurological level have a grade >3
E	Normal	Normal motor and sensory function

FRANKEL GRADING OF NEUROLOGICAL STATUS

GRADE	CRITERIA
A	Absent motor and sensory function
B	Absent motor , sensory present
C	Motor function present but not useful (2 or 3/5),sensory present
D	Motor function present and useful (4/5),sensory present
E	Normal motor and sensory function

POST INJURY STEROID ADMINISTRATION:

Patient with spine injury with associated neurological deficit should be given steroids as per NASICS III study [31]. The loading dose is 30 mg/kg of Injection Methyl prednisolone given over 15 minutes, followed by continuous administration of 5.4 mg/kg/hr for 24 hours if they came within 3 hours of injury and for 48 hours if they came between 3 and 8 hours.After 8 hours there is no indication for steroid administration.

SPINAL SHOCK:

Immediate axonal depolarization of axonal membranes after spinal trauma causes spinal shock. In this there is disruption of all cord function distal to injury, including reflexes [32]. It usually resolves within 48 hours of injury but may take weeks. So second neurological examination after 48 hours is mandatory to predict recovery. Return of bulbocavernous and anal wink reflex indicates the end of spinal shock. There are different types of spinal cord injury which includes the following [33];

CENTRAL CORD SYNDROME

This is a common spine injury and it is due to destruction of central area of spinal cord including both grey and white mater. The centrally located tracts in the corticospinal tracts are the most severely affected. Sensory sparing is variable. Prognosis for recovery is variable and more than 50 % recover bladder/bowel function or control and become ambulatory. Functional use of hands rarely recovers. It usually results from hyperextension injury in an older person with pre existing osteoarthritis of spine.

ANTERIOR CORD SYNDROME

It is due to damage to the anterior 2/3rd of spinal cord and characterised by complete motor and sensory (pain and temperature) loss distal to the level of injury. The posterior column is spared.

POSTERIOR CORD SYNDROME

It involves the dorsal columns of the spinal cord and produces loss of proprioception and vibration sense while preserving other motor and sensory function.

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BROWN SEQUARD SYNDROME

The most prognostically favourable incomplete spinal cord injury with more than 90 % of patients recovering bowel/bladder and ambulatory function. It occurs due to injury to one lateral half of cord and preservation of contralateral half characterized by ipsilateral loss of motor function and proprioception and contralateral loss of pain and temperature.

CONUS MEDULLARIS SYNDROME

It results from injury to the lumbar nerve roots and sacral cord. It is characterized by areflexic bowel, bladder and lower limbs with or without preserved bulbocavernosus and micturition reflexes.

CAUDA EQUINA SYNDROME

It results from injury to the lumbar nerve roots and sacral cord characterized by areflexic bowel, bladder and lower limbs.

RADIOLOGICAL EVALUATION

After prompt clinical and neurological examination, radiological examination should follow.

RADIOGRAPHS:

The patients are radiographed in supine position. The Xray beam and films are positioned in such a way to get the desired image without moving the patients to various positions in order to avoid secondary injuries. Accurate interpretation of the anteroposterior and lateral radiographs are essential.

The following parameters are evaluated - signs of instability, interspinous widening, translation of vertebra and vertebral body height loss . A motion segment is made up of two adjacent vertebrae and the intervening soft tissues. If a motion segment has all the anterior elements with one posterior element intact, or all the posterior elements and one anterior element intact, it will remain stable under normal physiological loads.

White and Panjabi defined instability as the loss of ability of the spine to maintain relationship between vertebrae under physiological loads. The checklist for the diagnosis of clinical instability includes the following in which a score of 5 or more indicates instability.

White and Panjabi Thoraco lumbar Instability Scale

Sl No	Element	Points
1	Anterior element unable to function	2
2	Posrerior element unable to function	2
3	Disruption of Costovertebral articulations	1
4	Sagittal plane displacement (T) > 2.5 mm; (L) > 4.5 mm	2
5	Sagittal plane angulation (T) > 5 deg; (L) > 22 deg	2
6	Spinal cord or Cauda equine damage	2
7	Dangerous load anticipated	1

Instability: Total Points >/= 5

Checklist for Diagnosis of Clinical Instability in Lower Cervical Spine

Element	Point Value
Anterior elements destroyed or unable to function	2
Posterior elements destroyed or unable to function	2
Relative sagittal plane translation >3.5 mm	2
Relative sagittal plane rotation >11 degrees	2
Positive stretch test	2
Medullary (cord) damage	2
Root damage	1
Abnormal disc narrowing	1
Dangerous loading anticipated	1

From White AA, Southwick WO, Panjabi MM: Clinical instability in the lower cervical spine: a review of past and current concepts, *Spine* 1:15, 1976.
*Total of 5 or more = unstable.

COMPUTED TOMOGRAPHY

In general CT scan is indicated for patients with suspected spinal fractures and dislocation that are not identified on plain radiographs and patients with incomplete visualization of the spinal column. Excellent bony detail of the fracture patterns usually can be obtained with CT scan. It is a very useful tool for evaluating,

-Wedge compression fracture,

-Missed second level fracture,

-Burst fracture with retropulsed fragment,

-Fracture dislocations,

-Bony chance fracture,

-Extent of canal compromise and

-Pedicle dimension of uninjured vertebra for preoperative planning.

MAGNETIC RESONANCE IMAGING

The MRI is indicated in every spinal cord injured patients to assess the status of the cord, disc and posterior ligamentous complex. It also detects the spinal cord edema and haematoma. It is 90 % sensitive and 100 % specific. Increased cord signals are associated with poor prognosis. The investigation of choice in spinal cord injuries is MRI. MRI is done to know the exact status of the cord and cauda equina to know the intactness of posterior longitudinal ligament, to rule out traumatic disc prolapse , to rule out soft tissue chance fracture and degree of canal compromise.

MANAGEMENT

The objectives of management of spinal fractures are

- Protection against further spinal cord injury
- Optimize conditions for maximal neurological recovery
- Maintain & restore spinal alignment
- Preventing spinal injuries in uninjured segments
- Obtain a healed and stable spinal column
- Prevention of morbidity due to prolonged recumbency and pain management.
- Facilitate rehabilitation.

Protocol for treatment :

All noncontiguous multilevel spinal fracture levels are classified into,

- Primary lesion
- Secondary lesion

A primary lesion is the level of vertebrae which is responsible for the symptoms and neurological deficit at the time of admission. A secondary lesion is the one which contributes or has the potential to contribute to patients symptoms or neurological deficits [34]. For example; this patient had fracture D12 and L3 vertebra with paraparesis of the both lower limbs corresponding to L3 level . Hence L3 is the primary lesion and D12 is the secondary lesion.

The treatment of multilevel noncontiguous spinal fractures follows the same guidelines as treating an isolated fracture in most of the circumstances. Factors to be taken into consideration are,

-spine instability and deformity,

-neurological injury,

-number of intact spinal segments in between fractures,

-patient's comorbid conditions,

-patient's willing for longer hospital stay.

Instability of spine, neurological deficit are the most important indications for surgical treatment in case of multilevel noncontiguous spinal fractures.

NON-SURGICAL MANAGEMENT:

It is indicated if the fracture is considered stable. If the vertebral fractures with kyphosis of less than 30° is considered stable, conservative treatment should be the first choice. Patients with severe comorbid conditions and other concomitant injuries such as head ,chest, abdominal injuries which precludes surgical intervention can be treated conservatively. Non surgical management indicated for stable spine fractures with no compression of neural elements including stable compression fractures of vertebral bodies, stable burst fractures, undisplaced fractures of lamina, spinous process which are treated with rest for 8 to 12 weeks [35]. Serial Xrays are obtained weekly for the first 3 weeks and then at 6^{th} week, 3^{rd} month, 6^{th} month and one year to look for any instability. All patients are given proper bed care preventing bed sores and other complications due to prolonged recumbency .Patients can be mobilized with help of Taylors brace and cervical collars after a minimum period of 4 weeks.

SURGICAL MANAGEMENT :

Indications for surgery:

-Unstable spinal fracture with neurological deficit

-Wedge compression fracture with 40 % loss of anterior body height

-Burst fracture with paraplegia

-Spinal canal compromise > 50%

Thoracolumbar Injury Severity Score helps to determine whether operative treatment of the thoracolumbar spinal injuries is appropriate for that particular fracture pattern [36].

THORACOLUMBAR INJURY SEVERITY SCORE

Sl NO	Fracture Mechanism	Points
1	Compression #	1
2	Burst #	1
3	Translation / Rotation	3
4	Distraction	4
	Neurological Involvement	
1	Intact	0
2	Nerve root	2
3	Cord, Conus medullaris Incomplete	3
4	Cord, Conus medullaris complete	2
5	Cauda equine	3
	Posterior Ligamentous complex Integrity	
1	Intact	0
2	Injury suspected	2
3	Injured	3

Score ≤3 → Non Operative Treatment

Score 4 → Non Operative / Operative Treatment

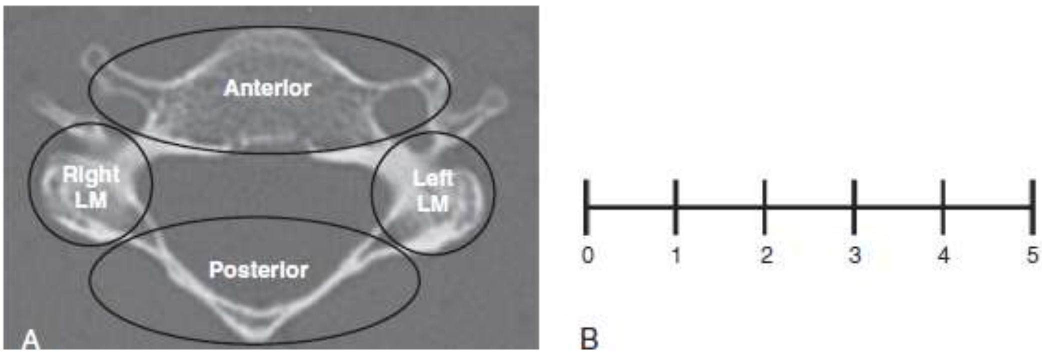
Score 5 →Operative Treatment

CERVICAL SPINE INJURY SEVERITY SCORING SYSTEM :

The Cervical Spine Injury Severity Score (CSISS) is based on analysis of four anatomical columns- anterior,posterior and two lateral columns. Each column is scored independently using the analog scale from 0 to 5. Undisplaced fracture is valued as 1, while increasing scores are given proportionally to the amount of displacement. Score 5 is given for the worst injury to a given column that is possible. Fractional values may be used. The CSISS is the sum from each column ranging from 0 to 20. [37]

PART INVOLVED	CSISS ANALOG SCORE
Anterior column	0-5
Right pillar	0-5
Left pillar	0-5
Posterior column	0-5
Total	0-20

Scores <5 are generally treated nonoperatively. Scores > 7 are usually treated surgically.



TIMING OF SURGERY:

It is best to operate the patient as early as possible to improve neurological recovery and early mobilization of the patient and to decrease hospital stay. In our institute MMC & RGGGH, surgery is done as soon as the patient is fit for anaesthesia.

SURGICAL APPROACH & TECHNIQUES:

CERVICAL SPINE:

Anterior approach

The anterior approach includes ventral decompression, reconstruction of the anterior column with bone graft or cage and stabilization with a plate. The advantages of the anterior technique include direct access to compressive pathology, supine positioning, familiarity, less postoperative pain, and reconstruction of the weight-bearing capacity of the spine. Further, open reduction of bilateral facet dislocations can be performed after discectomy if necessary. Disadvantages include inability to adequately correct lordosis, difficulty in extending cranially and caudally , postoperative dysphagia,hoarseness, respiratory embarrassment. Further, the anterior approach is more difficult at the cervicothoracic junction, where screw fixation may be difficult.

Posterior approach

The posterior approach is biomechanically more robust and extensile. It allows for open reduction of facet dislocations. The posterior approach is much easier to extend to the craniocervical or cervicothoracic junction if required. Disadvantages are the difficulties with the prone positioning in patients with unstable spines, greater muscle dissection with the potential for injury to the adjacent segment soft tissue, spontaneous fusion at adjacent segments and higher incidence of infection.

OPERATIVE TREATMENT OF CERVICAL SPINE INJURIES:

Unstable injuries of the cervical spine with or without neurological deficit requires operative treatment. It may be done with an anterior ,posterior or combined approach. If there is retropulsed bony fragments or disc causing canal compromise, anterior decompression with or without internal fixation is done. Laminectomy has limited role in case of cervical spine fractures and it may lead to postoperative instability. For posterior ligamentous or bony instability, posterior stabilization with internal fixation and bone grafting are indicated.

POSTERIOR APPROACH TO DORSO LUMBAR SPINE:

A posterior decompression is often performed in patient with symptomatic neural compression. In general, surgery is indicated most often in posterior longitudinal ligament injury as healing is unlikely with external immobilization. Here posterior fusion with instrumentation may be indicated to obtain stability, maintain alignment and to prevent chronic pain or progressive deformity. Pedicle screw system provides rigid fixation and is advantageous when lamina and spinous process are deficient. It avoids the morbidity of anterior exposure in patients who have associated pulmonary or abdominal injuries and involves shorter operative time, decreased blood loss and functional outcomes similar to anterior surgery .[38,39,40]

ANTERIOR APPROACH :

Anterior reduction, decompression and stabilization eliminate the risk of extruded disc fragments encroaching on the spinal canal and provide an effective method of reduction. It is also an easy method of stabilizing a single motion segment. Anterior discectomy, fusion and rigid anterior stabilization can also be done with posterior ligament injury. Anterior internal fixation provides stability often making an additional posterior surgery unnecessary. Anterior Surgery results in greater neurologic improvement than posterior decompression [41]. The main advantage in anterior surgery is the restoration of anterior column support, which provides greater mechanical stability and prevent late collapse in more unstable comminuted burst fractures than posterior instrumentation alone. [41,42,43]

COMBINED APPROACH

The complex pathology that is present with spinal trauma necessitates exposure of both anterior and posterior portions of spine. It can be done as staged procedure or sequentially in one procedure. The advantages of a combined approach includes maximization of canal clearance and immediate circumferential stability. The main drawback of combined surgery is the added morbidity of two separate procedures.

POSTERIOR DECOMPRESSION AND FUSION

The current generation of posterior spinal instrumentation primarily uses pedicle screw fixation. Biomechanically, there appears to be little difference in terms of stability between anterior and posterior fixation since it stabilizes the three columns of the spine.

IMPLANT OPTIONS

Implant options in the management of Thoracolumbar fractures include the following,

1. Posterior Instrumentation

Non segmental - Rod and hook system (Harrington rod)

Hybrid system - (Luque rod, Harrington rod with sublaminar wires).

Segmental system - Rod and hook constructs,

Extended pedicle screw constructs,

Short-segment pedicle instrumentation and Compression instrumentation.

2. Anterior Instrumentation

Anterior plate, screw and rod instrumentation,

Anterior struts.

The pedicle screw system includes the monoaxial and polyaxial system and depending on the locking screws available. They are single locking screws and double locking screws.

1. A Monoaxial pedicle screw has one axis, which means that its top segment or arm forms a continuous, linear, rigid structure with its bottom threaded segment [44].

2. The Polyaxial or Multiaxial pedicle screws are the modern standard when it comes to spinal fusion surgery. They have mobile arms, which can swivel freely of their threaded bottom segments. This helps reduce stress on the spinal column, as bracing rods stretching between two screws can flex and adapt more easily to body movements.

BIOMECHANICS OF PEDICLE SCREWS

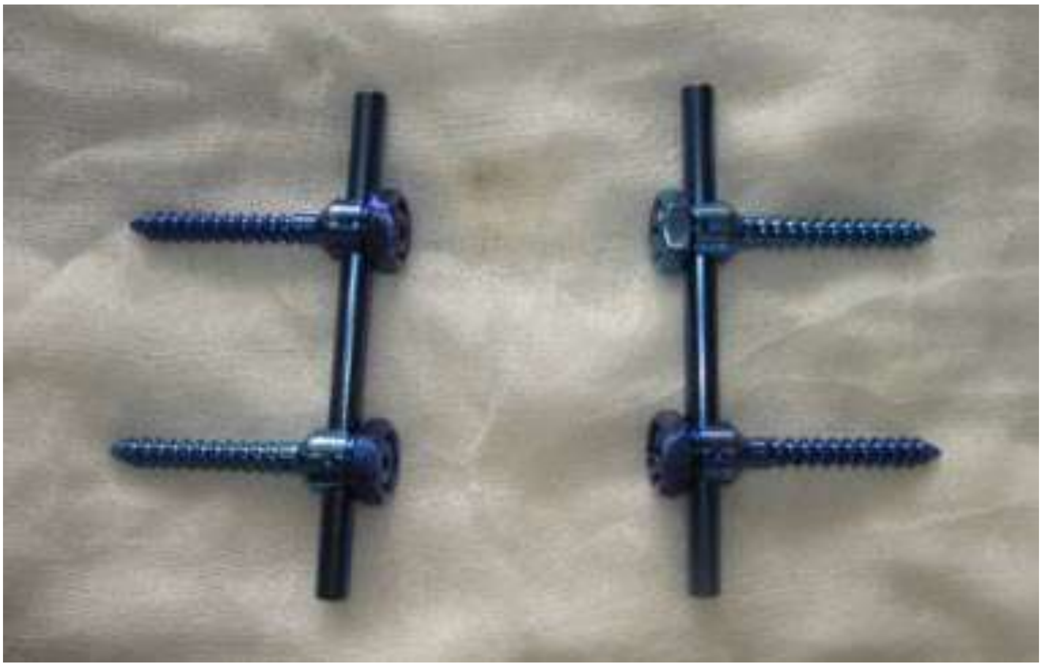
Pedicle screw systems provide a high degree of construction stability and afford good fixation to the spine. They provide three column fixation in unstable spinal injuries [45]. Being inserted into the vertebral body, these posterior devices can directly manipulate the intervertebral space. It also allows selective application of distraction, compression, lordosis, rotation and anterolisthesis or retrolisthesis forces. They are the most important factor that provides torsional stiffness in spinal constructs. Workers who advocate these implants for the spinal instability after burst fracture want augmentation with anterior column support to avoid exposing the screws to excessive cantilever loads that might cause bending failure or breakage.

OPERATIVE TECHNIQUES:

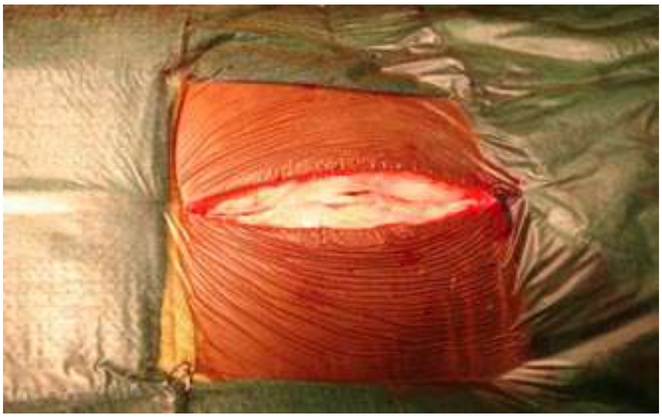
DORSOLUMBAR SPINE:

General anesthesia was given by a cuffed endotracheal tube. The patient was placed in prone position in operating table such a way the abdomen is free from pressure. The level of the injured spine as marked by C arm was taken as centre of the incision. The dorsolumbar spine is approached by midline incision and the fascia is incised in line with skin incision. The spinous processes is identified and the plane between spinous process and paraspinal muscles laterally was made. The paraspinal muscles are erased sub periosteally and reflected laterally with a self retaining spinal retractor. The pedicles are identified by a point where the middle of the transverse process and the longitudinal axis of the superior facet meet. The pedicle screws were passed under image intensifier control after probing the pedicle and measuring its depth. The commonly used screw size in our study includes 5.5 mm for thoracic pedicles and 6.5 mm for lumbar pedicles. Then the pedicle screws are bridged with two connecting rods fixed with an inner screw. Decompressive laminectomy is done depending upon the status of the neural canal . Wound closed in layers with a negative suction drain after attaining perfect haemostasis.

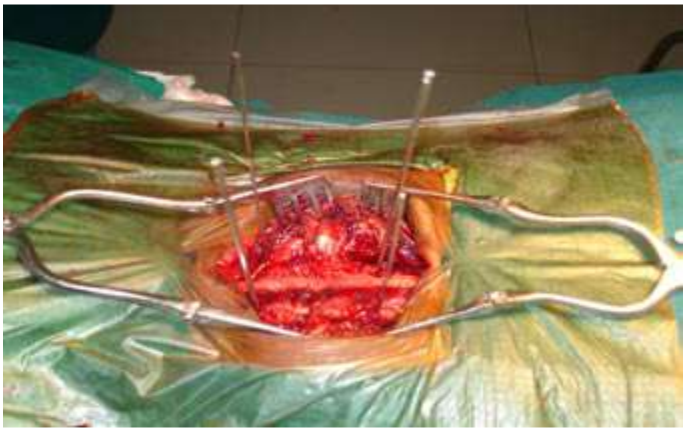
INSTRUMENTS AND IMPLANTS



INTRA OPERATIVE PICTURES:

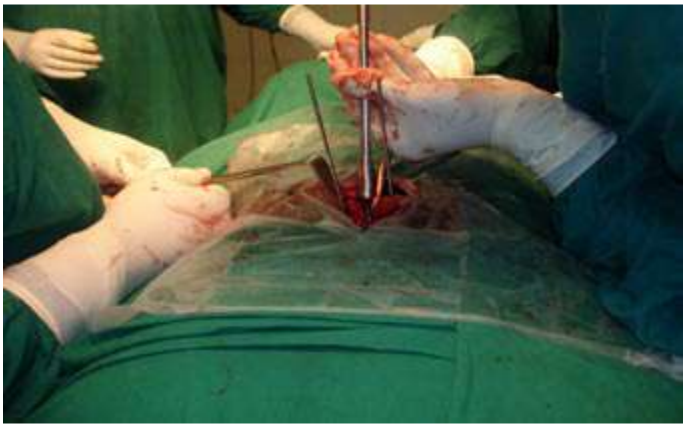


SKIN INCISION

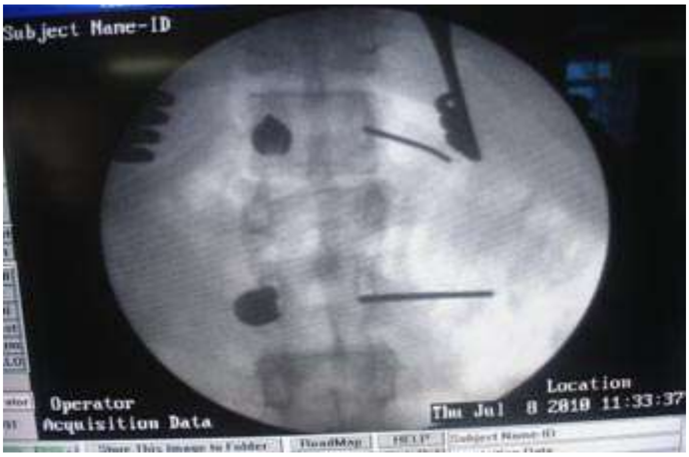


IDENTIFYING PEDICLE

ENTRY WITH AWL



SCREW INSERTION



SCREW IN SITU

SCREW WITH RODS

C ARM PICTURE

C ARM PICTURE


CROSS CONNECTING RODS FOR ADDITIONAL STABILITY

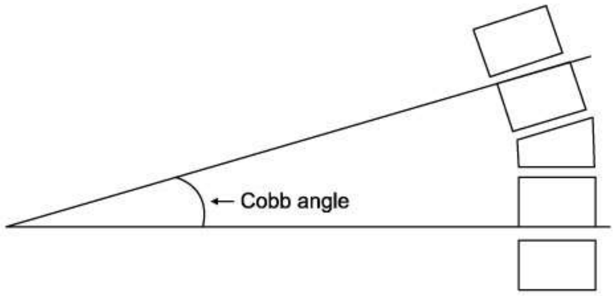
MATERIALS AND METHODS

Thrity two patients who presented with spinal fractures at more than one level with atleast one normal vertebra in between the fractured levels in our Institute of Orthopaedics and Traumatology during the period of 2013-2015 are studied retrospectively. Among the 32 patients with noncontiguous spinal fractures 26 were male and 6 patients were female.

All patients at the time of presentation was admitted in emergency trauma ward and resuscitated appropriately. A complete clinical and neurological examination is done for all the patients. The symptoms and signs were local symptoms such as cervical or back pain, restriction of motion, and neurological deficits from radiculopathies to paraplegia/quadriplegia. The American Spinal Injury Association (ASIA) scale was used for neurological evaluation and grading done with Frankel Grading scale. In our study 4 patients presented to us within 8 hours after injury and were administered Injection.Methyl prednisolone as per NACIS III protocol [46]. All patients are taken radiographs of Cervical, Dorsal,Lumbosacral spines both Anteroposterior and lateral views. Pelvis with both hips AP view is also taken for all patients to rule out associated pelvic fractures.

All fractured patients had CT scan of the spine to detect retropulsion of fractured fragments, canal compromise and for assessing pedicle dimensions. Ultrasonogram abdomen, CT brain was done in selected patients and associated injuries were ruled out. All the patients underwent Magnetic resonance imaging to know the status of the cord, integrity of the posterior longitudinal ligament, presence of disc herniations and the degree of canal compromise. Of all the spinal fractures admitted 90 patients were found to be having more than one level spinal fractures.They are classified as “contiguous” if no intervening normal segments between injured levels and “noncontiguous” if there is atleast one normal segment between the injured levels [47] .Using this criteria 32 patients were selected as noncontiguous multilevel spinal fractures and studied in detail.

The mode of injury, percent of anterior vertebral body compression, angle of deformity, and displacement percentage were determined for all levels of injury. Calculation of vertebral body angles was made with a modification of Cobb recommendation [48].



The unstable fractures were defined by clinical and radiological parameters. They include burst fractures with any one of the following criteria,

a. neurological deficit,

b. more than 50 % axial compression and

c. more than 25 % angulation,

d. wedge compression fractures involving middle column with neurological deficit and fracture dislocations with neurological deficit.The injuries were termed as primary and secondary lesions. “The primary lesion was the presenting lesion which seemed to be responsible for the patient’s symptoms or neurological signs on admission. The secondary lesion was an injury which contributed to, or had the potential to contribute the patient’s neurological deficit or symptoms.” [49]. The treatment is planned accordingly.

INCLUSION CRITERIA:

-patient aged 16-80 years

-two or more level involvement noncontiguous spinal fractures with atleast one normal vertebra in between.

EXCLUSION CRITERIA:

- Patient’s age <16 years and >80 years
- Pathological fractures
- Osteoporotic fractures
- very late presentation.

The patients are then classified under three groups.

Group A- patients treated by non-surgical means.

Group B- patients treated by surgery at one level.

Group C- patients treated by surgery at two or more levels.

POSTOPERATIVE MANAGEMENT

All the patients were turned sideways periodically in the immediate post operative period In case of cervical spine surgery, Philadelphia collar is applied to the patient post operatively. Drainage tube was removed at 48 hours. They were allowed to sit after wearing a Taylor’s brace or Philadelphia collar with a back support on 10th post operative day or more depending on the pain tolerance of the patient. Suture removal was done on 12th post operative day. Active assisted and passive exercises were taught to keep the joints supple. Clean intermittent self catheterization was taught in the post operative period.

FOLLOW UP

All the patients were advised to continue the Taylor's brace for the first 3 months after the surgery. They were advised follow up every month till 6 months and then every 2 months during the next 6 months.The minimum follow up in our study is 3 months and the maximum follow up is one year. During the follow up period the pain and working ability were assessed using Denis pain and work assessment scale and also evaluated clinically and radiologically. The following were evaluated,

1. Able to sit independently,
2. Walk with support,
3. Walk without support,
4. Bladder control,
5. Fracture consolidation and fusion and
6. Implant status

DENIS PAIN & WORK SCALE:

DENIS PAIN SCALE	CRITERIA

P1	No pain
P2	Occasional minimal pain; no need for medication
P3	Moderate pain, with occasional use of medications
P4	Moderate to severe pain, occasionally absent from work; significant changes in activities of daily living
P5	Constant ,severe pain; chronic pain medications

DENIS WORK SCALE	**CRITERIA**
W1	Able to return to previous employment (heavy works)or physically demanding activities.
W2	Able to return to previous employment (sedentary) or return to heavy works with restrictions.
W3	Unable to return to previous employment but works full time at new job.

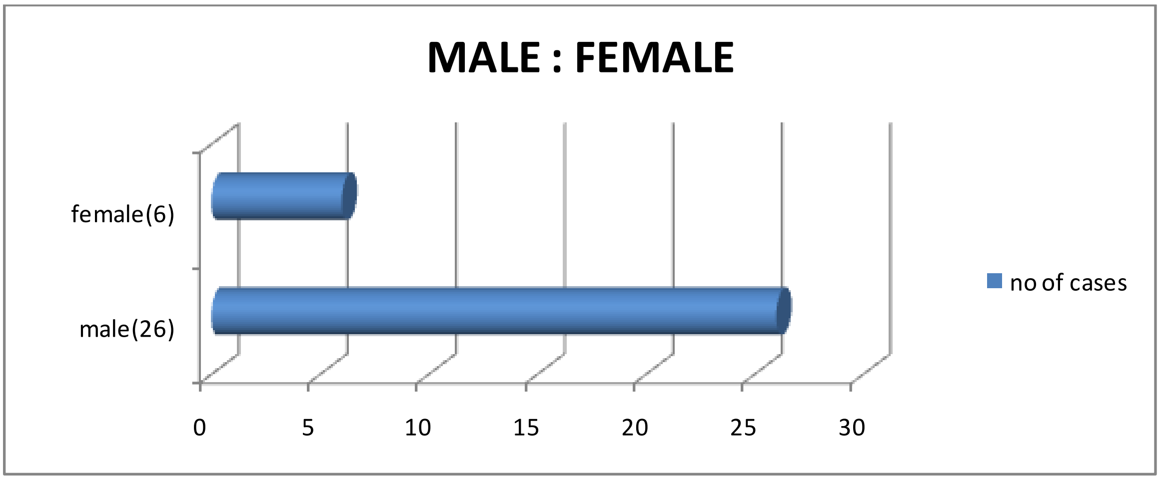
W4	Unable to return to full time work.
W5	No work, completely disabled.

RESULTS

In our study of noncontiguous multilevel spinal fractures, totally we had thirty two patients presented to our Institute of Orthopaedics and Traumatology , MMC & RGGGH from 2013-2015. Out of 32 patients 26 patients were male (81 %) and 6 patients were female (19 %). The male to female ratio was 4.3 :1 .

The mode of injury is being fall from height in 14 patients (44%) and road traffic accident in 18 patients (54%).

Chart 1 shows the Frequency of male and female in our study



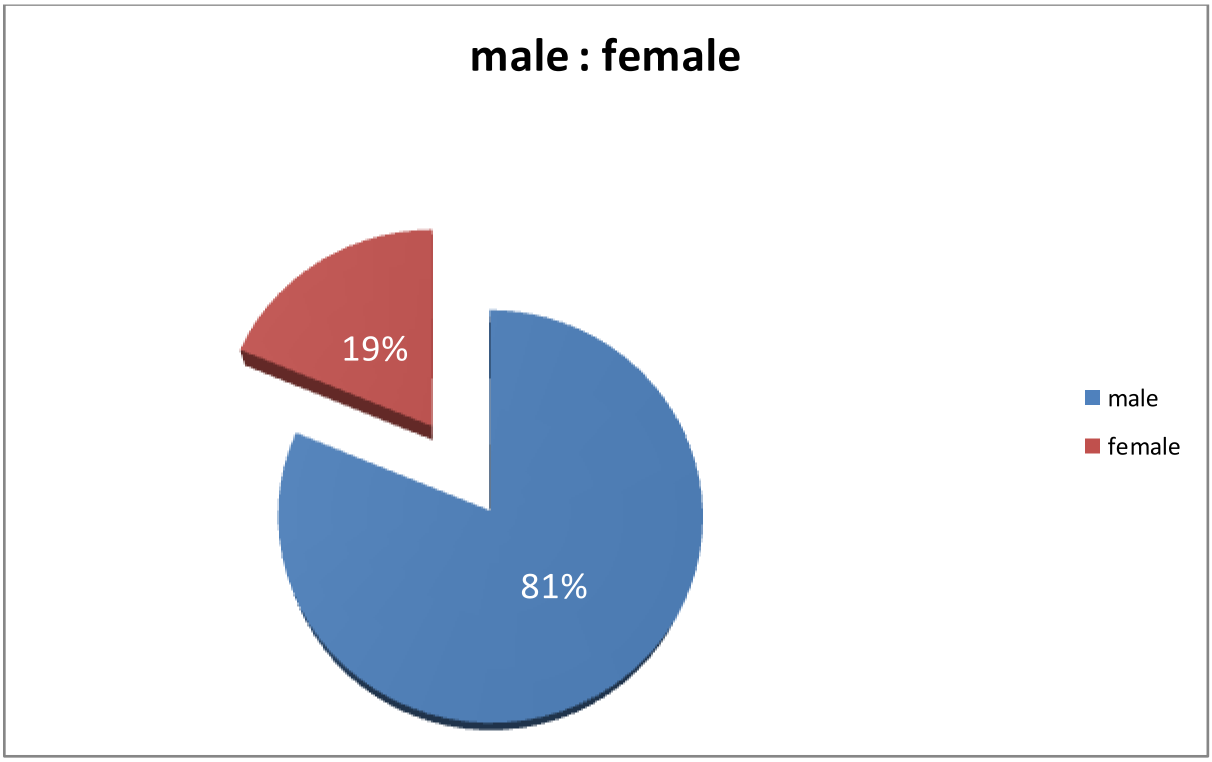
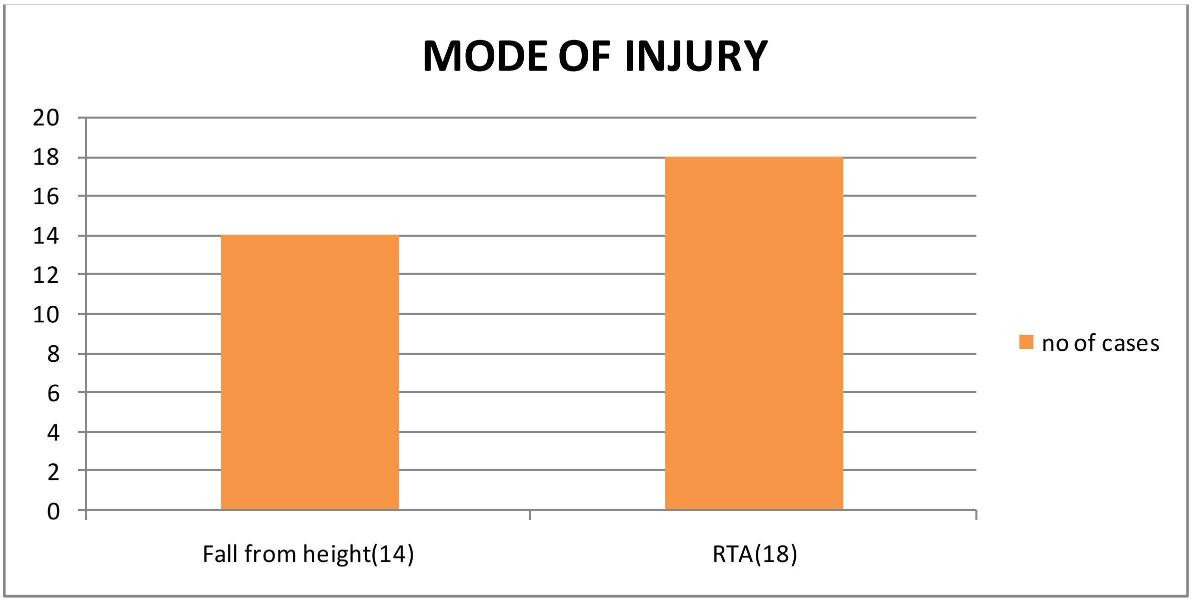


Chart 2 shows the mode of injury, frequency, and the percentage of distribution

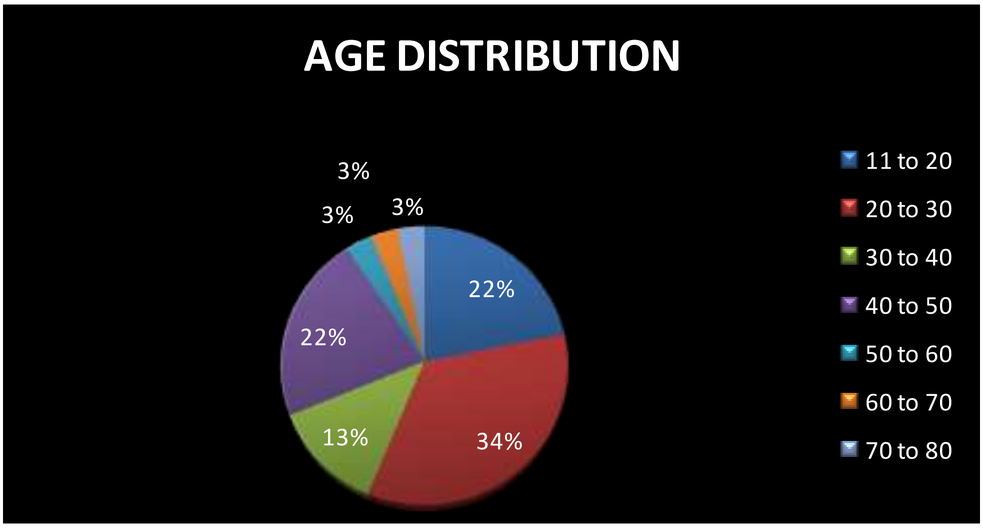


The age group included in our study who sustained noncontiguous multilevel spinal fractures are mostly young and middle aged group (range 17-75).The least aged patient is 17 years and most aged patient is 75 years. The mean age of the population is 33.5 years .

TABLE 1 shows the age wise distribution of cases,

Age range	No of patients	Percentage
11-20	7	22%
20-30	11	34%
30-40	4	13%
40-50	7	22%
50-60	1	3%
60-70	1	3%
70-80	1	3%
TOTAL	32	100%

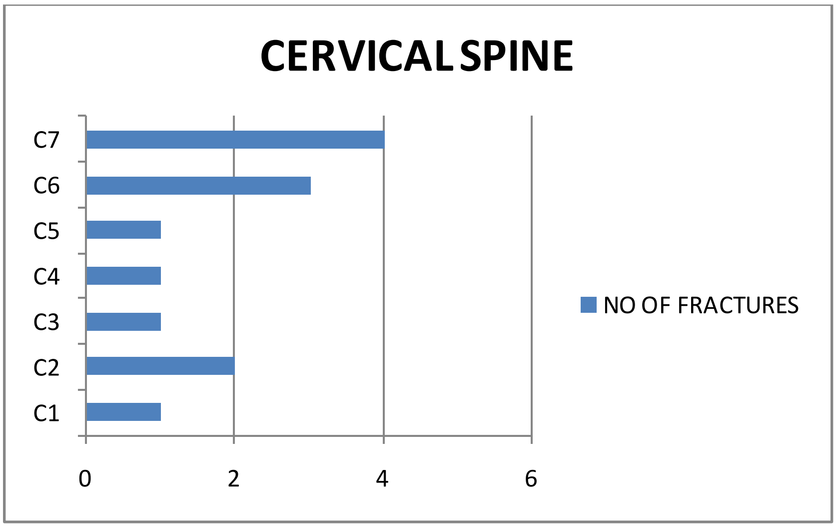
Chart 3 showing the age distribution:

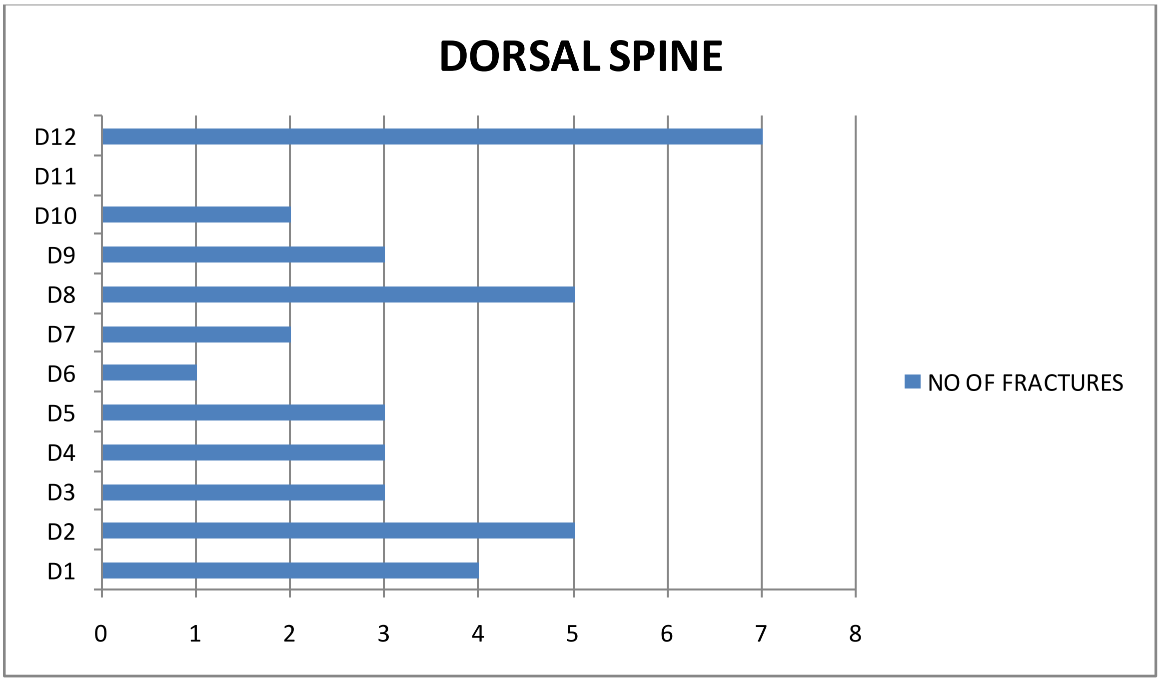


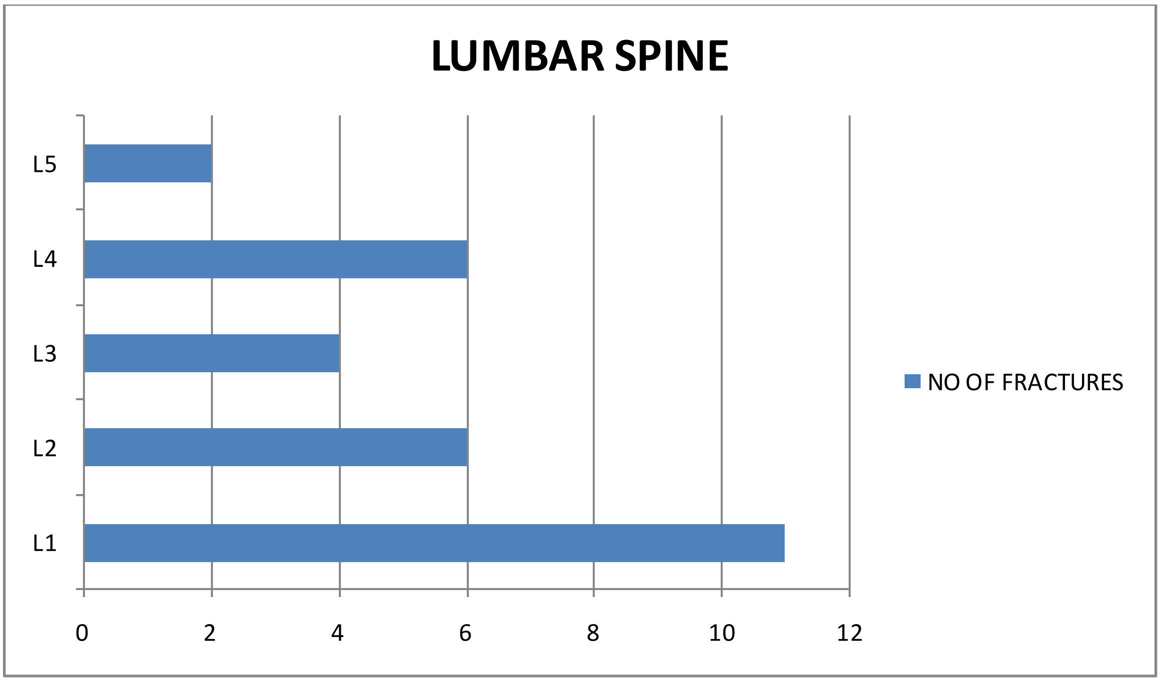
5 patients in our study {3,11,17,28,30} had associated injuries such as head injury, chest and abdominal injuries .Totally 4 patients presented within 8 hours of injury and are given intravenous Injection Methyl prednisolone succinate in the emergency trauma ward. Other patients did not receive any steroids (n=28).

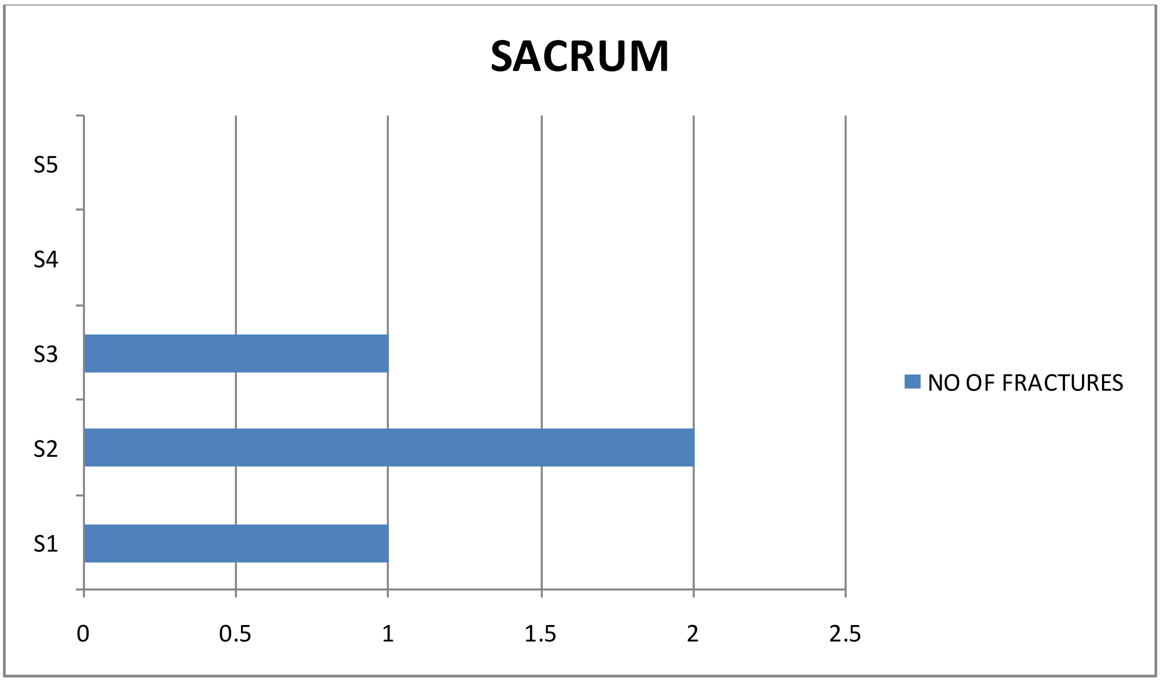
Total number of fractures in all 32 patients is 85 .The most common level of injury is at the dorsolumbar level .

<u>Chart 4 showing the incidence of fractures in each level</u>:


CERVICAL SPINE
C7
C6
C5
C4
C3
C2
C1
0
2
4
6
NO OF FRACTURES


DORSAL SPINE
D12
D11
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
0
1
2
3
4
5
6
7
8
NO OF FRACTURES



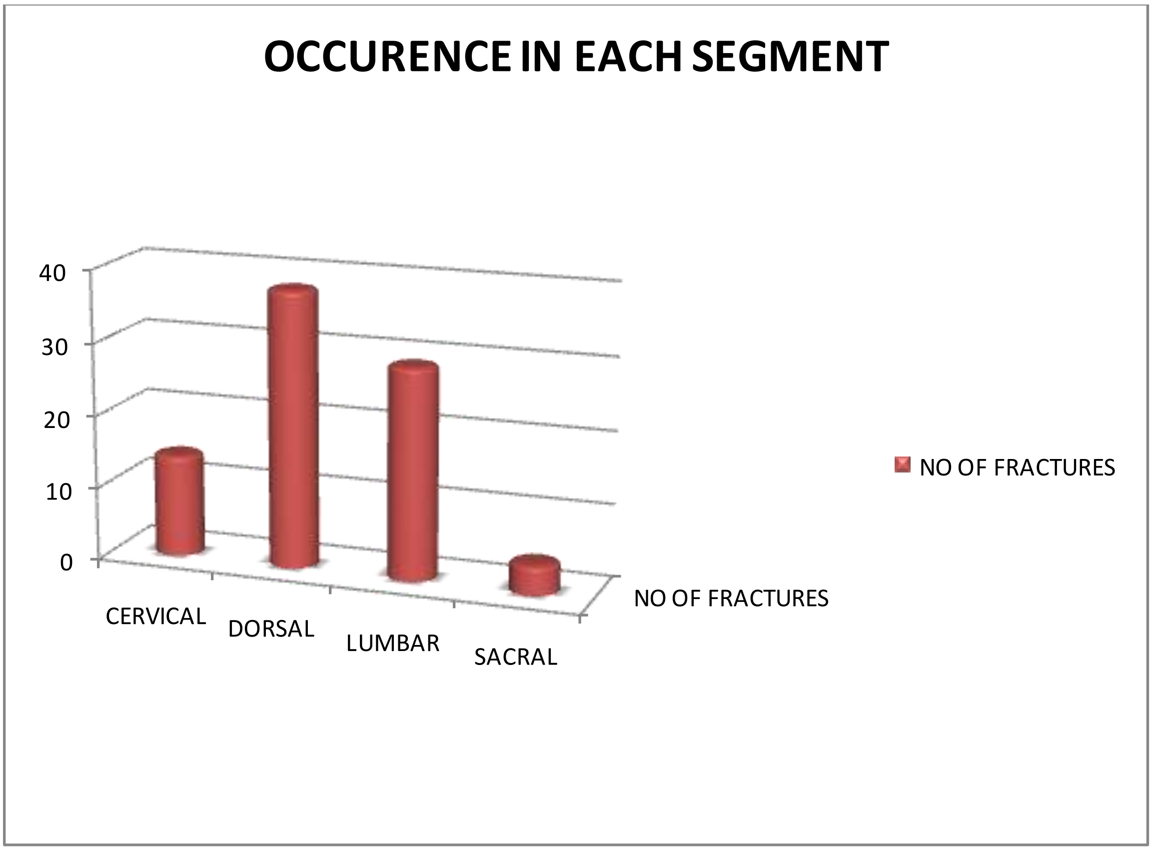


We didn't see coccygeal fracture in any of the cases.

<u>Table 2 showing most common level in each segment :</u>

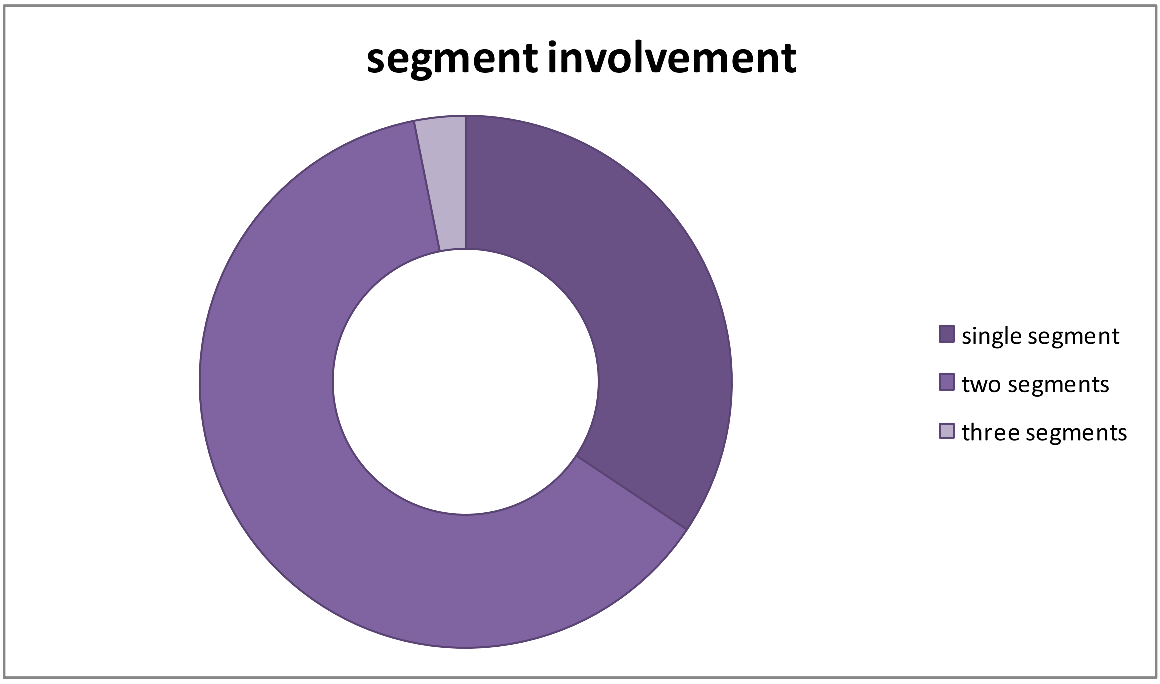
SEGMENT	LEVEL	NUMBER
CERVICAL	C7	4
DORSAL	D12	7
LUMBAR	L1	11
SACRUM	S2	2

Chart 5 showing occurrence of fractures in each segment:



Out of 32 cases , totally 11 patients (44 %), fractures involved only single segment (either Cervical,Dorsal,Lumbar,Sacral). 21 patients had involvement of more than one segment (66 %).

<u>Chart 6 showing segment involvement</u>:



Out of 22 cases involving multiple segments , one case had three segment involvement (5%) [Cervical,Dorsal & Lumbar]. In single segment involvement of 11 cases 6 involved Lumbar spine and 5 involved Dorsal spine. Cervical and Sacral single segment noncontiguous fractures did not occur.

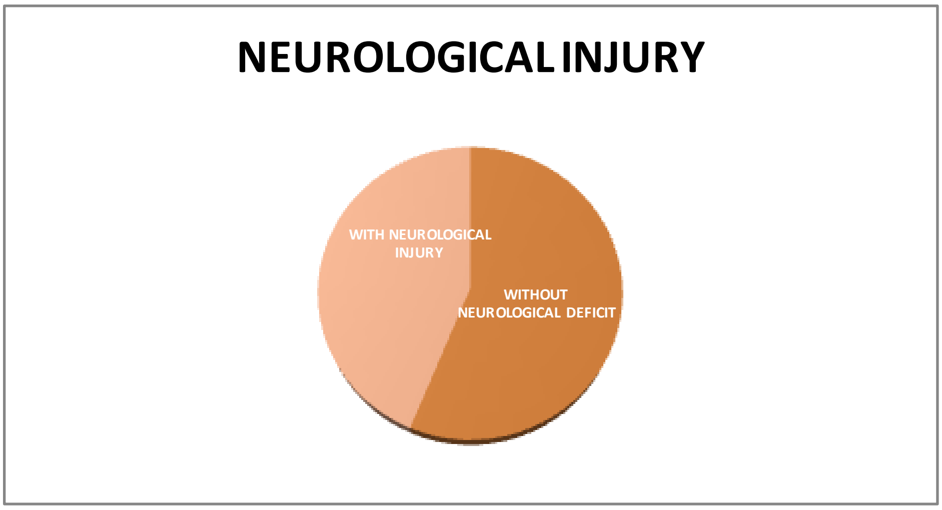
<u>Table3 showing combination of segments and their occurrence</u>

SEGMENT INVOLVEMENT	NUMBER

CERVICAL +DORSAL	7
CERVICAL + LUMBAR	2
DORSAL + LUMBAR	9
LUMBAR + SACRAL	2
CERVICAL + SACRAL	-
DORSAL + SACRAL	-
CERVICAL+DORSAL+LUMBAR	1

The most common combination is DORSAL + LUMBAR (n=9). The second most common is CERVICAL + DORSAL (n=7) .The most common type of fracture is anterior wedge compression fracture. (60%). Out of 32 cases 18 cases (56%) did not have any neurological deficit and 14 patients (44%) had neurological deficit ranging from mild weakness to complete quadriplegia.

<u>Chart 7 showing neurological status of patients:</u>



The neurological status is evaluated using Frankel grading and it showed,most common grade is E (53.5%).

TABLE 4 shows the percentage of the cases in Frankel grade:

FRANKEL GRADE	NO OF CASES	PERCENTAGE
A	5	15.5%
B	0	0
C	5	15.5%
D	5	15.5%
E	17	53.5%

In our study 4 patients had delay in diagnosing the second lesion of about 2 days. All patients are treated either conservatively , surgically based upon fracture patterns and neurological status. Surgery is done either at single level or more than one level. Follow up is done at an average period of 6 months. The patterns of injuries are listed below

Patient	**Mode of injury**	**Fracture location**	**Treatment**
1	FALL	D12,L2	Conservative
2	FALL	L1,S2,S3	Conservative
3	RTA	C1,C2,D12	Surgical
4	RTA	C7,D9,L1	Surgical
5	RTA	C2,D2,	Surgical
6	FALL	C5,C6,D3,D8	Surgical
7	RTA	D12,L3	Surgical
8	RTA	D8,D12,L2	Surgical
9	FALL	D5,D7	Surgical
10	FALL	D8,D12	Surgical
11	RTA	D9,L1,L3	Surgical
12	FALL	D12,L4,L5	Surgical
13	RTA	C3,C4,L2	Surgical
\14	RTA	D10,L1	Surgical
15	RTA	L2,L4	Surgical
16	RTA	D5,D7	Surgical
17	FALL	L1,L4	Conservative

18	RTA	D10,L2	Conservative
19	RTA	L1,L4	Surgical
20	FALL	C6,C7,D3,D4	Surgical
21	FALL	L1,L2,L4	Conservative
22	FALL	C2,L1,L3	Surgical
23	FALL	D5,D6,D8	Surgical
24	RTA	L1,S1,S2	Conservative
25	FALL	D12,L1,L5	Conservative
26	RTA	C7,L1,L2	Expired
27	RTA	C6,D3,D4	Conservative
28	RTA	C7,D4	Expired
29	FALL	L1,L4	Surgical
30	RTA	D8,D12	Conservative
31	FALL	D12,L3	Conservative
32	RTA	D9,D12	Conservative

GROUP- A : NON SURGICAL MANAGEMENT

S..NO	AGE	SEX	MODE OF INJURY	INVOLVED LEVELS				DIAGNOSIS	FRANKEL GRADE	FOLLOW UP (MONTHS)	PRESENT FRANKEL GRADE	DENIS PAIN SCALE	DENIS WORK SCALE
				C	D	L	S						
1	60	M	FALL	-	12	2	-	#D12,#BURST L2	D	8	D	P3	W5
2	75	M	FALL	-	-	1	2,3	#L1,S2,S3	E	12	E	P1	W2
3	22	M	FFH	-	-	1,4	-	#L1 TRANSVERSE PROCESS, BURST #L4	E	8	E	P3	W2
4	45	F	RTA	-	10	2	-	#D10 , # L2 WEDGE COMPRESSION	E	8	E	P3	W5
5	28	M	FFH	-	-	1,2,4	-	# ANTERIOR WEDGE COMPRESSION L1,L2,L4	E	12	E	P1	W1
6	24	M	RTA	-	-	1	1,2	#L1 WEDGE COMPRESSION,#S1,S2	E	6	E	P2	W4
7	21	M	FFH	-	12	1,5	-	#D12,#L1,L5	E	6	E	P1	W3
8	23	M	RTA	6	3,4	-	-	C6 SPINOUS PROCESS #, #D3,D4	E	5	E	P1	W3
9	28	M	RTA	-	8,12	-	-	#D8,#D12 ANTERIOR WEDGE COMPRESSION	E	12	E	P2	W4
10	50	M	FFH	-	12	3	-	SUBTLE COMPRESSION #D12,L3	E	11	E	P2	W2
11	38	F	RTA	-	9, 12	-	-	#D9, # WEDGE	E	8	E	P2	W4

								COMPRESSION #D12					
12	40	M	RTA	7,	1,2	-	-	#C7 BODY, #L1,L2 WEDGE COMPRESSION	A	-	-	-	EXPIRED
13	55	F	RTA	7	4	-	-	C7 COMPRESSION #,# D4 BURST	A	-	-	-	EXPIRED

GROUP B: SURGERY AT SINGLE LEVEL

NO	AGE	SEX	MODE OF INJURY	INVOLVED LEVELS				DIAGNOSIS	FRANKEL GRADE	SURGERY DONE LEVEL	FOLLOW UP MONTHS	PRESENT FRANKEL GRADE	DENIS PAIN SCALE	DENIS WORK SCALE
				C	D	L	S							
1	28	M	RTA	1,2	12	-	-	#C1,DENS#, #D12	C	C1	12	D	P2	W4
2	23	M	RTA	7	9	1	-	#C7,#D9,#L1	E	L1	12	E	P2	W3
3	42	M	FFH	5,6	3,8	-	-	C5-C6 # SUBLUXATIO N,# D3,D8	E	C5-6	12	E	P1	W2
4	20	M	RTA	-	12	3	-	#D12,BURST #L3	C	L3	12	D	P2	W3
5	20	M	RTA	-	8,12	2	-	#WEDGE COMPRESSION D8,D12, #BURST L2	E	L2	12	E	P1	W1
6	40	M	FFH	-	5,7	-	-	# WEDGE COMPRESSION D5, BURST # D7	E	D5	12	E	P3	W5
7	45	M	RTA	3,4	-	2	-	C3,C4 FACET #, #L2 BURST	C	L2	-	-	-	EXPIRED
8	50	M	RTA	-	10	1	-	D10 BURST #, #L1 WEDGE COMPRESSION	A	D10	-	-	-	EXPIRED
9	45	M	RTA	-	-	2,4	-	BURST # L2,WEDGE COMPRESSION #L4	E	L2	9	E	P1	W2
10	19	M	RTA	-	-	1,4	-	#L1,# L4 ANTERIOR WEDGE	D	L4	9	D	P2	W4

								COMPRESSION						
11	24	M	FFH	6,7	3,4	-	-	#C6,C7 SPINOUS PROCESS,#D3, D4 BURST	A	D3,4	6	A	P2	W5
12	36	M	FFH	-	5,6,8	-	-	#D5,D6,# D8 BODY	D	D8	8	E	P1	W2
13	18	F	FFH	-	-	1,4	-	#L1,L4 BURST	D	L1	3	D	P3	W5

GROUP C- SURGERY AT MULTIPLE LEVELS

S.NO	AGE	SEX	MODE OF INJURY	INVOLVED LEVELS				DIAGNOSIS	FRANKEL SCORE	FOLLOW UP MONTHS	PRESENT FRANKEL GRADE	DENIS PAIN SCALE	DENIS WORK SCALE
				C	D	L	S						
1	28	M	FFH	-	8,12	-	-	# D8,# D12 BURST	D	12	E	P4	W5
2	17	F	RTA	-	9	1,3	-	WEDGE COMPRESSION# D9,BURST#L1,L3	E	12	E	P2	W5
3	45	M	FFH	-	12	4,5	-	D12 BURST #, #L4	C	7	C	P2	W5
4	20	M	RTA	-	5,7	-	-	BURST # D5,D7	E	9	E	P1	W2
5	25	M	FFH	2	-	1,3	-	TYPE II ODONTOID FRACTURE, #L1,L3 BODY	E	7	E	P1	W4
6	18	F	RTA	2	2	-	-	TYPE II ODONTOID #, # D2	A	NIL	A	P2	W5

ANALYSIS OF GROUPS

Analyzing the results, there was no significant difference between all the three groups in terms of age, sex, mode of injury and fracture patterns.

In group A , out of 13 patients 10 were male and 3 were female. The mean follow up period was about 9.6 months. All patients except two had the same neurological status in the subsequent follow up. Their radiography during subsequent follow up showed improvement in kyphotic angle about a mean of 2 degrees . Two patients expired in group A pre operatively – one patient associated with head injury and was on assisted ventilation and another patient expired due to cardiorespiratory arrest with aspiration pneumonitis. Out of 11 patients excluding 2 expired patients, 4 had a pain scale of P1 (37%) and 4 patients had pain scale of P2 (36%)and 3 had pain scale of P3 (27%) . In the eleven patients , one patient had work scale of W1 (9%), 3 patients had work scale W2 (27.5%), 2 patients had work scale W3(18%), 3 patients had work scale of W4 (27.5%), 2 patients had work scale of W5(18%) during the follow up.

In group B, out of 13 patients 12 were male (92%) and 1 female patient (8%). At time of presentation 2 patients had Frankel Grade A (15%), 3 patients had Frankel Grade C (23%), 3 patients had Grade D (23%), 5 patients had Grade E (39%) neurological status. All patients are operated at single level primary fracture level . The secondary fracture level is treated conservatively. All patients are followed for a mean period of 12 months. Two patients expired post operatively one patient due to aspiration pneumonitis after seven days. Out of 13 patients operated 4 patients had improved neurological status of one Frankel grade post operatively .The correction of Kyphotic angle is about an average of 4 degrees at operated site and 2 degrees at non- operated site. During the follow up out of 11 patients excluding expired patients, 4 patients had Denis pain scale P1(36%), 5 patients had Denis pain scale P2(46%), 2 patients had P3(18%). Out of eleven patients, one patient had work scale W1 (29%) ,3 patients had work scale W2 (22%), 2 patients had W3(14%), 2 patients had W4(14%), 3 patients had W5 (21%)work scale.

In group C, out of 6 patients 4 patients were male and 2 were female. On time of presentation one patient had Frankel grade A(16%), one patient had Frankel grade C (17%), one patient had Frankel grade D (17%), 3 patients had Frankel grade E (50%) .All patients were operated at two levels of fractures. The mean follow up period was 12 months. During the follow up two patients had improvement in neurological status by one Frankel grade. 2 patients has Pain scale of P1 (22%), 3 patients has pain scale of P2 (34%), one patient has pain scale P4. One patient had work scale of W2 (17%), two patients had work scale of W4 (33%), 3 patients has work scale W5 (50%) .

Initial mobilization in Group A was about 9.2 +/ - 1 week (range 6-12 weeks) which is longer when compared to groups B & C which is 4+/- 1 week (range- 3-5 weeks)and 2+/- 1 week (range-1 -3 weeks). Group B was longer than Group C . Group B had lesser mean operating time and intraoperative blood loss than group C.

<u>Table 4 showing comparison of immobilization time, operating time, average blood loss:</u>

GROUP	IMMOBILISATION TIME(WEEKS)	OPERATING TIME (min)	BLOOD LOSS(ml)
A	9.2 +/- 1	0	0
B	4 +/- 1	100+/- 25	Average 200
C	2+/-1	150+/- 25	Average 350

<u>Table 5 showing neurological status post operatively:</u>

Pre op neurology	Post op neurology
Frankel Grade A (15.5 %)	A TO A (3 CASES)
Frankel Grade B (0%)	-
Frankel Grade C (15.5%)	C TO D (2 CASES) C TO C (1 CASE)

Frankel Grade D (15.5 %)	D TO E (2 CASES) D TO D (3 CASES)
Frankel Grade E (53.5 %)	E TO E (11 CASES)

COMPARISON OF NEUROLOGICAL STATUS AFTER TREATMENT IN GROUP A, B AND C:

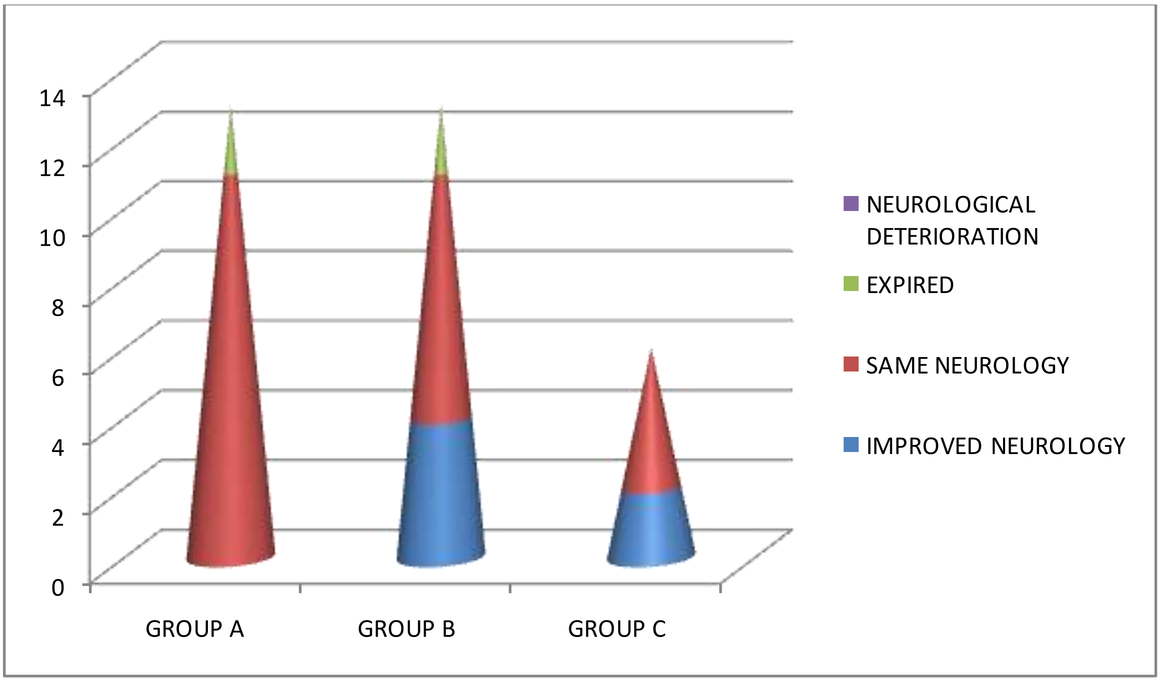


Table 6 comparing present pain and work scale in all three groups:

DENIS PAIN SCALE	NO IN EACH GROUP		
	A	B	C
P1	4	6	2
P2	4	3	3
P3	-	-	-
P4	-	-	1
P5	3	2	-

DENIS WORK SCALE	NO IN EACH GROUP		
	A	B	C
W1	1	1	-
W2	4	3	1
W3	-	-	-
W4	3	2	1
W5	3	5	4

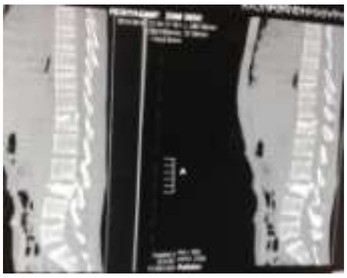
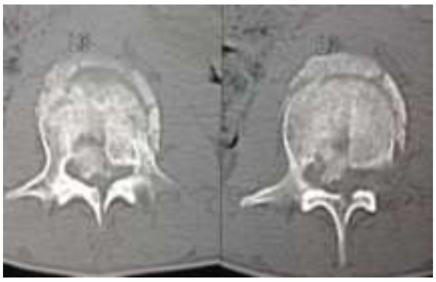
COMPLICATIONS

Three patients (two in group A and one in group B) developed pressure sore which was treated with intravenous antibiotics, regular dressings and log rolling. Two patients in group A developed Urinary tract infection on catheterization during the period of bed rest. In surgically treated patients one patient in Group B and two of Group C developed superficial surgical site infection and was managed by intravenous antibiotics and wound debridement. Two patients of Group C had increased neurological deficit immediate post operative period but it returned to previous pre operative levels after 2 weeks.

ILLUSTRATED CASE 1:

20 years male presented to emergency room with h/o RTA (2 wheeler Vs 4 wheeler) with c/o pain in the back region. After initial resuscitation of the patient detailed clinical and neurological examination was done. Patient had neurological deficit with a muscle power of 2/5 in both the lower limbs and sensations were preserved in both lower limbs. X ray DL spine showed fracture at D12 and L3 . CT spine was taken in emergency ward. It showed an anterior wedge compression fracture of D12 and burst fracture at L3 level. L3 fracture was found to be unstable with loss of 50% of body height. MRI showed there is anterior wedge compression at level D12 and a burst fracture at L3 with canal compromise and compressing the spinal cord. Patient was planned to be operated at L3 level and to treat D12 fracture conservatively. Posterior stabilization was done for L3 level with pedicle screw at L2, L3 and L4. Decompression laminectomy at L3 was done to relieve pressure effect on spinal cord.

Case 1:Pre op

IMMEDIATE POST OP :

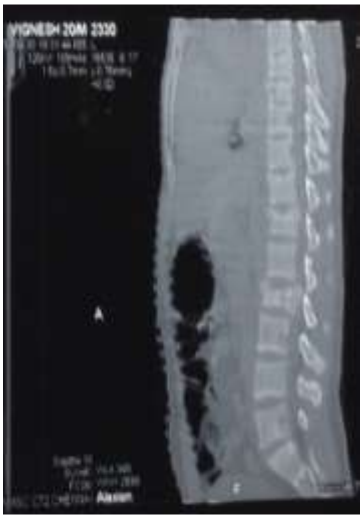

1 YEAR FOLLOW UP :

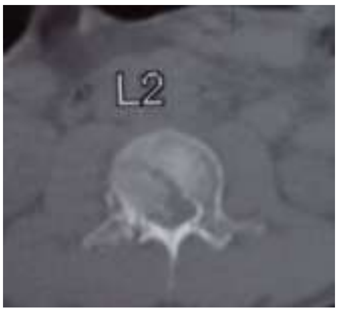
ILLUSTRATED CASE 2:

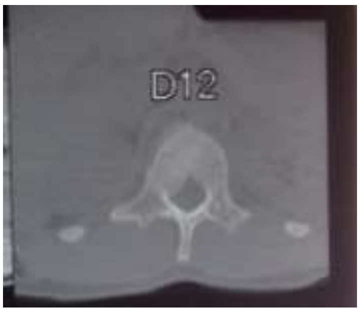
20 years male manual labour presented to emergency trauma ward with h/o fall from height (10 feet tree) with c/o pain in the back region. After initial resuscitation of the patient detailed clinical and neurological examination was done. Patient had no neurological deficit. X-ray DL spine was taken and it showed fracture of D12 and L2. CT spine was taken in emergency room. It showed anterior wedge compression fracture of D12 and burst fracture L2. L2 fracture was found unstable with loss of 50% body height. MRI showed anterior wedge compression fracture at D12 and burst fracture at L2 with canal compromise and spinal cord compression. Patient was planned to be operated at L2 level. Posterior stabilization done at the levels L1, L2, L3. D12 fracture is managed conservatively. Patient was mobilized with Taylor's brace at the end of 2^{nd} week. Patient was followed after one year. Patient had no neurological deterioration. Patient had a pain scale of P1 and was able to get back to his labour work W1.

PRE OP :

pre op x rays 1







IMMEDIATE POST OP :

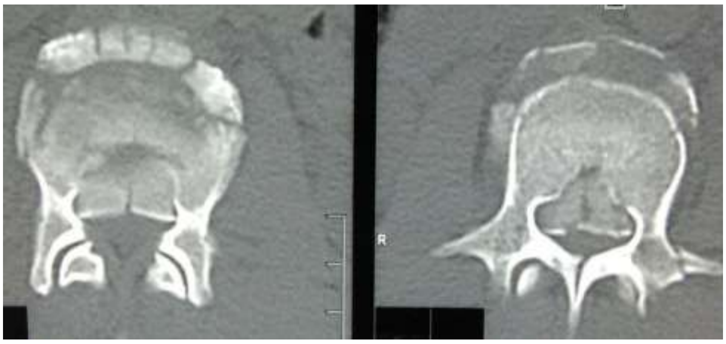
1 YEAR FOLLOW UP :

ILLUSTATED CASE 3 :

48 years old male patient admitted in emergency trauma ward with h/o accidental fall from tree and sustained injury to the back. Patient had pain in the lower back region. After initial resuscitation a thorough clinical and neurological examination was done. Patient had no neurological deficit.

X ray LS spine AP and Lateral views showed fracture L2 and anterior wedging fracture of L4. CT scan was taken and it showed burst # L2 with retropulsion of fragments into the canal and anterior wedge compression # L4 with < 20 % loss of height. MRI showed fracture L2 impinging on the cord and cord changes . Posterior stabilisaton was done at L2 level with pedicle screws at L1,L2,L3 . Fracture L4 was treated conservatively. Patient was mobilized at 10 th post operative day with Taylor’s brace. At 10^{th} month follow up patient was walking. No neurological deterioration. Kyphotic angle improved 6 degrees at L2 .Patient had a pain scale of P1 and work scale of W2.

PRE OP :



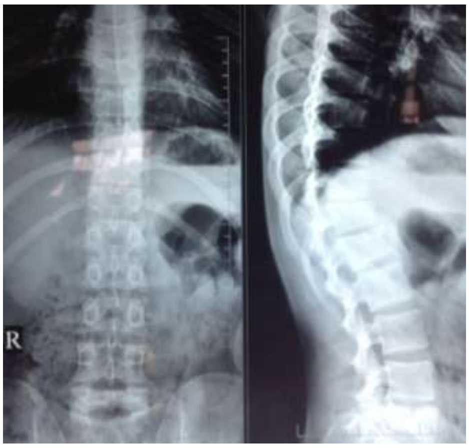
IMMEDIATE POST OP :

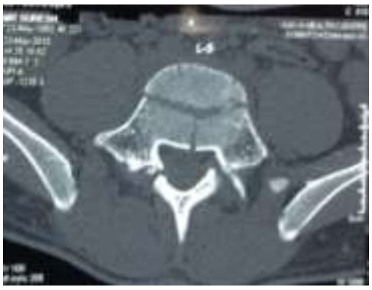
10 MONTHS FOLLOW UP :

ILLUSTRATED CASE 4:

21 years male admitted to emergency trauma ward with alleged h/o accidental fall from first floor and sustained injury to back. Patient had h/o back pain. After initial resuscitation patient was examined clinically and neurologically. Patient had tenderness over dorso lumbar region and patient had no neurological deficit .Bladder and bowel functions were normal. Xray DL spine AP and lateral views showed # D12 and # L1 and # L5. CT scan of the spine showed anterior wedge compression fracture D12 and L1 with <20% reduction in body height. There was a body Fracture of L5 but it was minimally displaced and no canal compromise was noted. It was confirmed by canal diameter measurement values.MRI showed no impingement of spinal cord. Patient was managed conservatively with Taylor’s brace and patient was allowed to turn side to side to prevent prolonged recumbency complications. Patient was mobilized from bed and allowed to walk after 4 weeks. Patient had pain at fracture region and was managed with analgesics. At 7 month follow up patient was walking without support and had a pain scale of P1 and work scale of W3.

AT ADMISSION :





4 MONTHS FOLLOW UP :

7 MONTHS FOLLOW UP

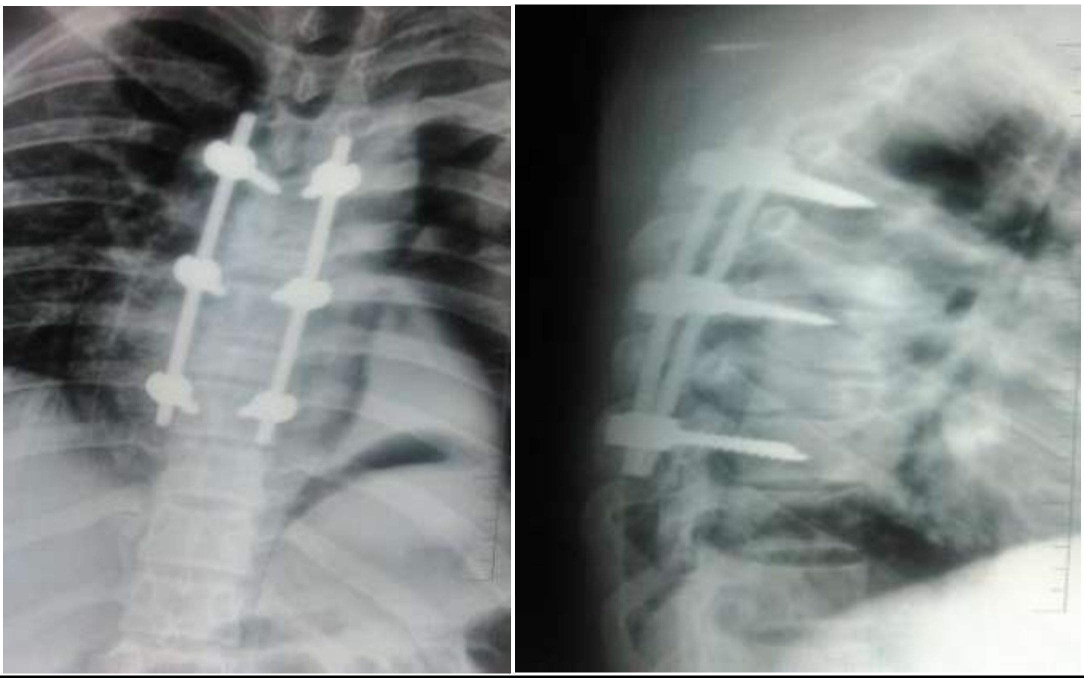
ILLUSTRATED CASE 5 :

20 years male patient presented to emergency trauma ward with h/o Road traffic accident (accidental fall from 2 wheeler) and sustained injury to the back. Initial resuscitation of the patient was done. A thorough clinical and neurological examination was done. Patient had no neurological deficit .

X ray of Dorsolumbar spine AP and lateral views showed fracture of D5 and D7 vertebra with >50% reduction in vertebral body height. CT spine was taken . There was burst fracture at both D5 and D7 levels . D6 level was normal. MRI spine showed # D5 and D7 with adjacent prevertebral hematoma causing spinal cord compression. Since both fracture sites are unstable posterior stabilization was done for both levels D5 and D7 with pedicle screws at levels D4,D6 and D8. On one year of follow up patient had no neurological deterioration and had a pain scale P1 , work scale of W2.

PRE OP :

IMMEDIATE POST OP :



1 YEAR FOLLOW UP :

DISCUSSION

Multilevel noncontiguous spinal fractures occurs in patients with high energy trauma. In our study, age group of 20-30 years are most commonly affected and males have higher incidence than females. Fall from height and road traffic accidents is found to be mostly associated with multilevel noncontiguous spinal fractures. The definition of multilevel non contiguous study is variable. In this study,we followed the definition given by Iencean [47] which states that presence of even one normal level between fractured levels is termed as multilevel noncontiguous spinal fractures. There is rise in incidence of this type of fractures in modern era owing to the increase in high energy trauma and improved diagnostic facilities [50].

Delay in establishing the second fractures has been reported frequently in literatures [51] . In our study we found 4 patients had delay in diagnosis of the second fracture . That 4 patients had a delay in diagnosis because of the associated other injuries such as head trauma and chest contusion . But this delay didn’t cause any ill effects on the outcome. To avoid missing the diagnosis of a second fracture site, a careful whole spine CT screening should be done. MRI is a very important radiological tool for diagnosis and planning the treatment [52,53]. Especially when an upper fracture is responsible for neurological deficit a lower level fracture must be always excluded. 5 patients in our study [CASE - 3,11,17,28,30] had associated injuries such as head, chest and abdominal injuries. When admitting within within 8 hours of injury, Injection Methylprednisolone was administered according to the results of the **National Acute Spinal Cord Injury Study (NASCIS-III).**

Treating multilevel non contiguous spinal fractures follow the same guidelines followed for spinal fractures occurring at single level [49]. But treating a multilevel spine fracture requires special attention and must be individualized. Certain factors must be taken into account, such as neurological deficit, spine instability, deformity, the number of intact spinal units between the two fractures [49] and also patient's desire for less days of hospital stay. Special consideration must be given to all lesions in their treatment to avoid conflicting influences of the multiple lesions. The major factors aiding in planning of the treatment of multilevel noncontiguous spinal fractures are stability of the fracture sites and associated neurological deficits. Conservative treatment should be advised for fractures which are stable. In our study, if both the fractures are found to be stable and are not associated with neurological injury are treated conservatively (group A).This also includes the patients with severe co morbid conditions and patients not willing to undergo surgery. Prolonged immobilization , prolonged recumbency and associated pressure sore,urinary tract infection due to long time bladder catheterisation and longer hospital stay are the main disadvantages.

If one fracture is unstable and contributes to neurological deficit it is treated surgically .The second fracture if stable and did not cause neurological deficit it is treated conservatively (group B). In case the upper level fracture causes the cord injury and neurological deficit, the lower level fracture is corrected surgically only if the lower level fracture is unstable radiologically. The surgical principles are same as that of treating a single level such as canal decompression, deformity correction, alignment restoration and spinal stabilization. There is good result in this group in terms of neurological recovery, allowing early mobilization and deformity correction radiologically. Some literatures say that there may be loss of alignment and deterioration of one level if another level alone surgically treated [54]. But in our study we found that the conservatively treated site is stable and good radiological outcome in subsequent follow up and also there was no deterioration in neurological status. The mean operating time, surgical blood loss, post operative infections are also lower in group B compared to group C.

When both the fractures are unstable and if kyphotic angle is greater than 30 degrees or if the neurological deficit is caused by multilevel compressions both levels are treated surgically (Group C). Clinical and radiological outcomes in this group were better . There was significant decrease in immobilization time also. High Surgical blood loss, lengthy operating time and high rate of infections are seen in this group. However during surgery at one level the other fractured level must be protected to avoid deterioration of neurological status. But in our study, in all three groups there was no deterioration of neurological status noted. Radiologically, the improvement in deformity in terms of kyphotic angle was better in Group C compared to Group A and B. in our study we didn't find any loss of correction of the vertebra in any of the group.

The mortality rate in our study is about 4 out of 32 patients studied. Two patients in group A expired due to associated head injury and poor general condition .Two patients in Group B post operatively, one had associated cervical spine injury which was a secondary lesion expired on the third post operative day . This emphasis on protecting the second fracture while operating the other fracture . Another patient with multilevel lumbar fracture expired after seven days due to aspiration pneumonitis .This emphasis the role of Ryle's tube feeding in spine injured patients.

During the follow up , all patients except the expired patients showed improved or same level Frankel neurological grade .No deterioration was observed. Pain and work scale showed good improvement in all groups.

CONCLUSION

In high energy trauma patients with spinal fracture the presence of other levels of fractures must be excluded. Routine clinical and radiological screening should be done in all spinal fractures to rule out multilevel non contiguous fractures. Radiographs of the whole spine is essential in emergency setup. Life support should be the important element in initial management of multi level noncontiguous spinal fractures. Treatment planning should be done after CT and MRI evaluation. Treatment should be individualized from patient to patient depending on the neurological status, stability of spine, and patient's condition. These fractures can be treated either conservatively, surgically or combination of both. Clear knowledge in decision making for individual fractures is essential. Conservatively treated cases should be monitored carefully for deterioration of condition.

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CONSENT PROFORMA

Title : "   ANALYSIS OF MULTILEVEL NONCONTIGUOUS SPINAL

FRACTURES- A RETROSPECTIVE STUDY   "

Aim: Aim of this study is to evaluate the incidence, levels involved, patterns of fractures, neurological deficits created, treatment options and outcome of noncontiguous multilevel spinal fractures.

Consent: I have been explained about the nature of injury, the method of treatment, potential complications, the outcomes of not undergoing the surgery, and need of regular follow up visits in my own vernacular language and also the need for documenting my Xrays and my clinical records.

I hereby give my consent for this study.

Signature

CLINICAL PROFORMA

Name:

Age/ Sex:

IP No:

Address:

Unit : Ward :

Date of Admission:

Date of Surgery:

Date of Discharge:

Diagnosis:

Associated Injuries:

Pre operative Frankel grade:

Investigations:

1. Radiograph 2.CT/MRI

3. Blood investigations 4.Chest X-Ray

5. ECG 6. Others

Operative Procedure :

Rehablitation :

Post operative Frankel grade :

Post op advice:

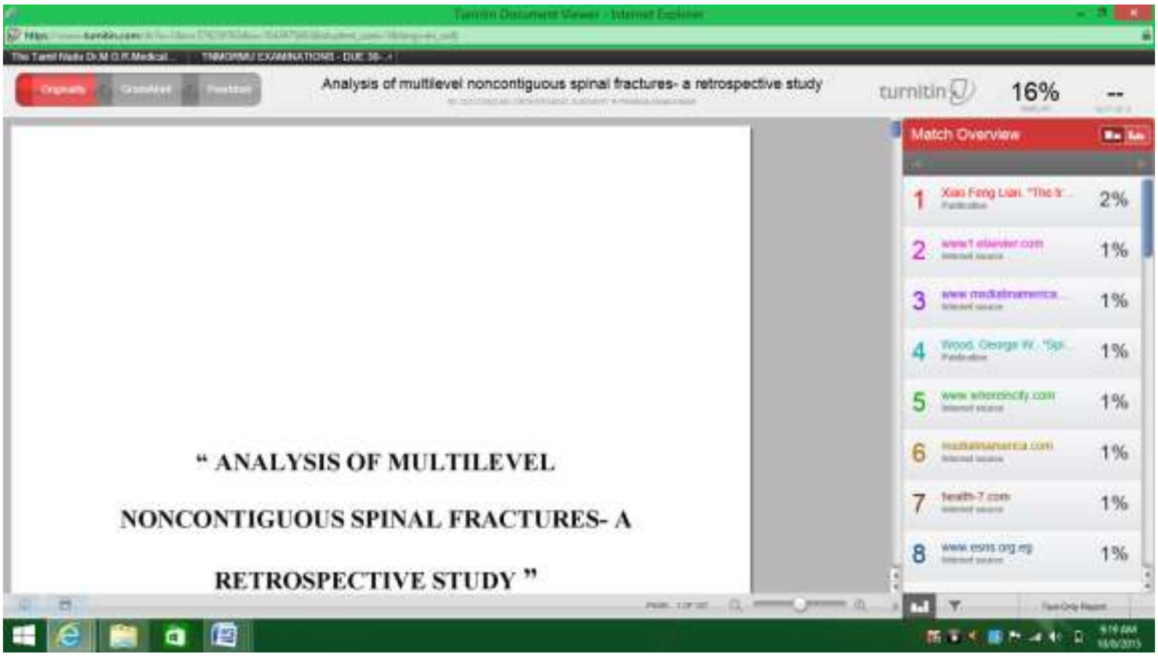
Follow up:

Denis Pain assessment scale

Denis work assessment scale

Complications:

Remarks: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